ILLINOIS STATE
GEOLOGICAL SURVEY
BULLETIN No. 19
WHEATON QUADRANGLE

CORRECTIONS

The following corrections in the report are due to editorial and typographical errors. Please note:

P. 27, 1. 12, for "till" read "materials of the terminal moraine."

P. 47, 1, 19, for "drift or till" read "other stratified drift."

1, 21, before "stratified" insert "other".

P. 50, last column of last table, altituded should be followed by minus sign (-). Average should read 664 (-) instead of 615.

STATE OF ILLINOIS
STATE GEOLOGICAL SURVEY
FRANK W. DeWOLF, Director

BULLETIN No. 19

Geology and Geography

OF THE

Wheaton Quadrangle

BY

ARTHUR C. TROWBRIDGE

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STATE GEOLOGICAL COMMISSION.

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STATE GEOLOGICAL SURVEY,
UNIVERSITY OF ILLINOIS, July 9, 1912.

Governor C. S. Deneen, Chairman, and Members of the Geological Commission:

GENTLEMEN—I submit herewith a report on the Geology and Geography of the Wheaton quadrangle, and recommend that it be published as Bulletin No. 19.

Professor Arthur C. Trowbridge, the author, bases the report on field work done in 1907-08 under the direction of Professor R. D. Salisbury, Consulting Geologist of the Survey. The author was formerly engaged in teaching at the University of Chicago and is now at the State University of Iowa. His experience has enabled him to make this a report of unusual interest to residents of the Wheaton region and to teachers and students of geology and physiography everywhere. Naturally, the report treats especially of the glacial history of the region, but the references to hard-rock geology and to the full geological history are quite adequate.

The Survey is greatly indebted to the author and to Professor Salisbury, and to others who furnished choice illustrations.

Very respectfully,
FRANK W. DEWOLF,
Director.

INTRODUCTION.

LOCATION AND EXTENT OF THE REGION.

The area under consideration is that covered by the Wheaton, Ill., topographic sheet made by the State and United States Geological Surveys in cooperation. It is about 250 square miles in extent, and comprises the western three-fourths of Dupage county as far south as the third tier of sections of Naperville township, and north as far as the southern tier of sections in Cook county (See Plate II in pocket). Wheaton occupies the geographic center of the area, which also includes the towns of Naperville, Downers Grove, Lombard, Glen Ellyn, Bloomingdale, Bartlett, and West Chicago. It is drained by East Branch and West Branch of Dupage river, which run parallel in a general southerly direction, to join a few miles south of the area.

CHAPTER I—PRE-GLACIAL HISTORY IN BRIEF.

DIVISIONS OF GEOLOGIC TIME.

That this area was once beneath the sea is evidenced by the limestone which underlies the region everywhere, and comes to the surface in several places. Not only does the character of the rock itself indicate that it was deposited in water, but it contains numerous fossils, all of which are the remains of animals that lived in the sea. We shall see that the region has been beneath the sea, not once only, but several times during its history.

Geologic time has been divided into eras, and the eras have been divided into periods. The events of these time intervals are recorded in the rocks. Those of successive eras are separated from one another by breaks in the record. For instance, over wide areas the group of rocks formed in the Proterozoic era were uplifted from the sea in which many of them were deposited, were folded, twisted, broken, and exposed for a long period to the action of the atmosphere and running water. All these events occurred before the beginning of the Paleozoic era. Then, at the beginning of Paleozoic time, the rocks were again submerged and other sediments laid down upon them. These later sediments constitute the Paleozoic rocks. The interval between the upraising of the Proterzoic rocks and the deposition of the Paleozoic rocks separates the Proterozoic and Paleozoic eras. The periods are separated from one another by similar intervals during which conditions on the earth's surface changed, but the series of events between the successive periods were not as great as between the different eras.

The events which took place between the various eras and periods are inferred from the relations between the rock formations involved, and their geographic distribution. Thus, the lowest Silurian beds lie on the uneven surface of the topmost Orodovician, indicating that the Ordovician rocks had been eroded before the Silurian rocks were laid down. Moreover, in several localities, as in Ohio and Indiana, the Ordovician rocks are found to be warped from their original horizontal position more than the later Silurian rocks. This indicates that a slight movement of the Ordovician rocks took place before the deposition of the Silurian strata.

The following is a table of Geologic time divisions, beginning at the bottom with the first or Archeozoic era and proceeding to the most recent or Cenozoic era at the top. The subdivisions (epochs) of the periods are omitted except in the cases of the Cambrian, Ordovician, and Silurian. For these the subdivisions are given because it was at these times that the rocks which underlie the Wheaton quadrangle were formed. Excepting the glacial drift, the youngest rocks in the quadrangle are of Niagaran age.

Principal subdivisions of geologic time scale.

Eras.	Periods.	Epochs.
Cenozoic	Recent	
	Pleistocene	
	Pliocene	
	Miocene	
	Eocene	
Mesozoic	Cretaceous	
	Comanchean	
	Jurassic	
	Triassic	
Paleozoic	Permian	
	Pennsylvanian	
	Mississippian	
	Devonian	
	Silurian	Cayugan
		Niagaran
		Alexandrian
	Ordovician	Cincinnatian
		Mohawkian
		Canadian
	Cambrian	Potsdam (Saratogan)
		Acadian
		Georgian
Proterozoic	Keweenawan	
	Upper Huronian or Animikean	
	Middle Huronian	
	Lower Huronian	
Archeozoic		

ROCK FORMATIONS BENEATH THE REGION.

The limestone of the Wheaton quadrangle has been identified as Niagran. It is similar in appearance and constitution to rocks of known Niagaran age in other regions in the interior of the continent, for example along the Chicago drainage canal. Furthermore, the nearly horizontal beds exposed in the drainage canal would, if continued, underlie this region at no great depth. Again this rock, as at the quarries at Naperville, contains the same fossils as the Niagaran limestone elsewhere. That the rock which appears at the surface in the vicinity of Naperville underlies the whole region is known from the records of wells which go down to bed rock. All the wells which strike rock at all, strike the same sort of rock as that which outcrops at Naperville.

The rocks below the Niagaran limestone are known only from deep borings. In Downers Grove, Naperville, and West Chicago, deep wells have been bored which go through the Niagaran limestone, and through some of the formations which underlie it as far down as the top of the

Cambrian. In the 2021 feet of its depth, the Downers Grove well goes through the Niagaran beds of the Silurian system and the Cincinnatian, Mohawkian, and Canadian series of the Ordovician system. The Naperville well shows about the same series of strata and so does the West Chicago well, so far as it goes.

Record of the Naperville city well. (No. 12[1]).

Character of rock.	Age.	Thickness.
		Feet.
Loam and loose rock	Pleistocene and recent	20
Limestone	Niagaran	95
Limestone streaked with shale	Cincinnatian	190
Limestone	Galena-Trenton (Mohawkian)	341
Sandstone	St. Peter (Canadian)	129
Limestone streaked with shale	Lower Magnesian (Canadian)	61
Limestone		100
Shale		3
?		6
Sandstone		5
Limestone		315
Sandstone	Upper part of Potsdam	155
Dirty sandstone		5
		1,425

Record of West Chicago well. (No. 4[1]).

Character of rock.	Age.	Thickness.
		Feet.
Soil and loose rock	Pleistocene	90
Limestone	Niagaran	269
Shale and limestone	Cincinnatian and probably Mohawkian	346
Sandstone	St. Peter (Canadian)	134
		869

Record of Downers Grove well. (No. 63[1]).

Character of rock.	Age.	Thickness.
		Feet.
Surface material	Pleistocene	100
Limestone	Niagaran	170
Shale interbedded with limestone	Cincinnatian	210
Limestone	Galena-Trenton (Mohawkian)	337
Sandstone with slight amounts of limestone, shale, and sandy marl	St. Peter (Canadian)	321
Limestone with some sandstones and shales	Lower Magnesian (Canadian)	762
Sandstone	Upper part of Potsdam	121
		2,021

[1] Numbers refer to wells as located and numbered in Pl. II.

From these sections we get some idea of the physical history of the region since Cambrian times. The Potsdam sandstone was laid down as sand in the sea which covered this part of the continent during the latter part of the Cambrian period. Sedimentation continued in this sea all through the Ordovician period, except for a possible break between the Mohawkian and Cincinnatian. The fact that the Galena-Trenton beds apparently do not occur in their usual thickness in the West Chicago well, suggests a period of erosion after these beds were deposited, during which their upper layers were partially removed before the Cincinnatian shales were deposited. There were some changes of conditions during the Ordovician period, which resulted in alternating deposits of sand (now St. Peter sandstone) and limestone. At the end of the period conditions were such that the muds of which the Cincinnatian shales are made were in process of deposition. After the end of the Ordovician no deposition took place in the region until the Niagaran epoch of the Silurian period. This doubtless means that this part of the continent was land during the Alexandrian epoch. By the beginning of the Niagaran epoch the sea had again advanced over the region, and limestone-making materials were again deposited.

Although there are no beds later than the Niagaran in the Wheaton quadrangle, Devonian fossils have been found in cracks in the limestone at the Elmhurst quarry 2 miles east of the eastern border of the quadrangle,[1] and so it is probable that the area was covered by the sea in Devonian times. The absence from the region of the rocks deposited in the Devonian sea is due to their removal by erosion.

After the Devonian period the region was land and exposed to erosion most of the time until the Pleistocene or glacial period. The beds of the Niagaran rocks are nearly horizontal, showing that there has been no folding or other great deformation of the strata since they were laid down.

CEMENTATION OF THE SEDIMENTS.

The rocks which underlie the region are hard and firmly cemented. The materials of which they are made were laid down in the sea in very small pieces, as sand, mud, or as the fragments of the hard parts of animals. The sand grains were firmly cemented together by the deposition between them of small quantities of mineral matter. The result was the sandstone as we see it today. In the same way the muds were cemented to make shales.

Limestone is composed chiefly of calcium carbonate, which is taken from the sea water by marine animals and utilized by them in making shells or other hard parts. After the animals die, their secretions accumulate on the bottom of the ocean, often in fragments. In clear seas where little sand or mud is being deposited, these animal remains constitute the greater part of the materials laid down. They accumulate very slowly but if sufficient time be allowed they may build up beds of great thickness, as they did in the Ordovician and Silurian seas. The fragments of shells, corals, etc., laid down in those seas were later cemented together to make limestone, just as the sand and mud particles that were associated with them were made into sandstone and shale.

[1] Weller, Stuart, Jour. Geology, vol. 7, 1899, pp. 483-488.

SURFACE OF THE BED ROCK UNDERLYING THE DRIFT.

The Wheaton quadrangle is covered by a mantle of stiff stony clay, with occasional patches and layers of sand and gravel. In many places this mantle is more than 100 feet thick. It is known as the glacial drift, since it was deposited by an ice sheet which formerly overspread this region, together with a large part of the northern portion of North America. Below the drift the solid rock is often reached by wells. The shape of the surface of the rock under the drift could be known if there were enough borings down to it; but those wells which go down to rock are so far apart that much of the rock surface is untouched by borings. Although there are not enough deep wells to show the rock surface in detail, there are enough to give us much information about it. (See table of well records in appendix.)

Some well drillers of the county state that the rock surface is practically level, and that its depth in any place can be computed if the elevation of the well site is known. A study of the well records, however, does not bear out this conclusion. By noting the elevations of well sites from the topographic map and subtracting the distance to rock the elevation above sea level of every point on the rock surface to which a well has been bored can be determined. A calculation of this kind based on the record of 61 wells indicates that the surface of the rock is quite irregular in a small way, though without great relief. Ten well records chosen at random from different parts of the area show a maximum difference of 78 feet in the elevation of the rock surface.

Table showing depth and altitude of bed-rock in feet.

Well number.[1]	Elevation of surface above sea level.	Depth to rock.	Elevation of rock surface above sea level.
	Feet.	Feet.	Feet.
17	750	170	580
26	755	140	615
56	755	108	647
44	775	124	651
41	750	112	638
29	750	130	629
46	775	117	658
10	715	125	589
72	700	72	628
61	770	120	650

[1] See Plate II for locations, and appendix for complete records.

While no attempt has been made to determine the details of the pre-glacial surface, enough facts have been observed to enable us to judge of its general character. The lowest points found on the surface of the bed-rock are about 580 feet above sea level—about the level of the surface of Lake Michigan. This elevation is found in two places, in the south central part of sec. 23, Winfield township (well No. 17), and in the central part of sec. 3, Bloomingdale township (well No. 27).

The highest point of the rock surface, so far as known, is at the Naperville quarries, where it is at an elevation of approximately 680 feet. The rock surface in this region therefore, has a relief of at least 100 feet, and it is probably somewhat more, because it is not likely that its highest and lowest points have been discovered by borings. The two extremes in elevation, at Naperville and in Winfield township, are 6 miles apart, giving an average slope between these points of 100 feet in 6 miles, or about 15 feet per mile. In sec. 21, Bloomingdale township, a well at an elevation of 815 feet struck rock at 140 feet from the surface, while one hardly a quarter of a mile away, where the surface is 15 feet lower, reached rock at a depth of 158 feet (Nos. 35 and 36). At this place the slope of the rock surface is at least 128 feet per mile. Between Naperville and the canning factory at Eola, 5 miles away, there is a difference in elevation of the rock surface of 80 feet. The maximum relief of the present surface is about 220 feet, or 120 feet more than that of the pre-glacial surface. So far as known, there is no slope on the rock surface as steep as the greatest slope on the present surface.

Six records along the western edge of the area indicate that the rock surface in this portion of the district has an average height above sea of 675; about 2 miles farther east its surface is at a height of about 620 feet; in the central part of the area it lies in general at about 640 feet; and along the east edge of the area it averages about 630 feet in height, as nearly as can be determined from known records. This would seem to show that at the time the glaciers began to cover the district, its highest part was along the west side, and its lowest somewhere near its middle. The lowest part of the region today is along the west edge of the quadrangle and its highest part, along the terminal moraine 2 miles further east. The lowest places of the present surface are over some of the higher parts of the old surface, and the higher parts of the present surface over the lower parts of the old one.

CHAPTER II—THE GLACIAL PERIOD IN NORTH AMERICA.

EVIDENCES OF GLACIATION.

The greater part of the northern portion of North America was covered by great ice sheets during the Pleistocene period of the Cenozoic era. This is shown by both depositional and erosional features.

DEPOSITIONAL FEATURES.

The greater part of North America north of the white area on the accompanying map (Pl. I) is covered in large part by a mantle of unconsolidated material, varying in thickness from a few inches to 500 feet or more, which is absent entirely from the region to the south. This mantle is known as *drift*.

Though the drift at any one place is made up rather largely of material which is not far from its place of origin, it also contains a very noticeable amount of material which has come from a distance. Much of this foreign material in the drift over Illinois is of rock which resulted from the solidification of lavas in regions several hundred miles farther north.

The drift is made up of particles of all sizes and, in general, there is no regularity in their arrangement. Clay particles, sand grains, pebbles, and bowlders are intermixed without order. This unsorted or *unstratified* drift is known as *till*. Nothing but glacier ice deposits material of just this sort in just this way.

Besides the till, the drift contains in some places sand and gravel which have evidently been sorted and separated from the rest of the deposit by the action of water. This sorted, or stratified, drift may occur as pockets or layers in the till, or it may lie over or under the till. Masses of till may sustain similar relations to stratified drift. The stratified drift is incidental to the melting of the glacier ice.

The drift is spread quite generally over the north part of North America, indicating that the depositing agent was of great extent. Moreover, its distribution is relatively independent of the elevation of the surface on which it rests, for it occurs on hilltops as well as in valleys—the agent which deposited it covered hills and valleys alike. A wide-spread cover of glacial ice would act in this way.

The topography of the surface of the drift is characteristic. Its elevations and depressions have no regular relation to each other except where its original surface has been modified by the cutting of streams. Its surface is simply a rolling plain with its moderate elevations and depressions distributed without order or arrangement, such as might be produced by the deposits of a widely spread mass of ice.

EROSIONAL FEATURES.

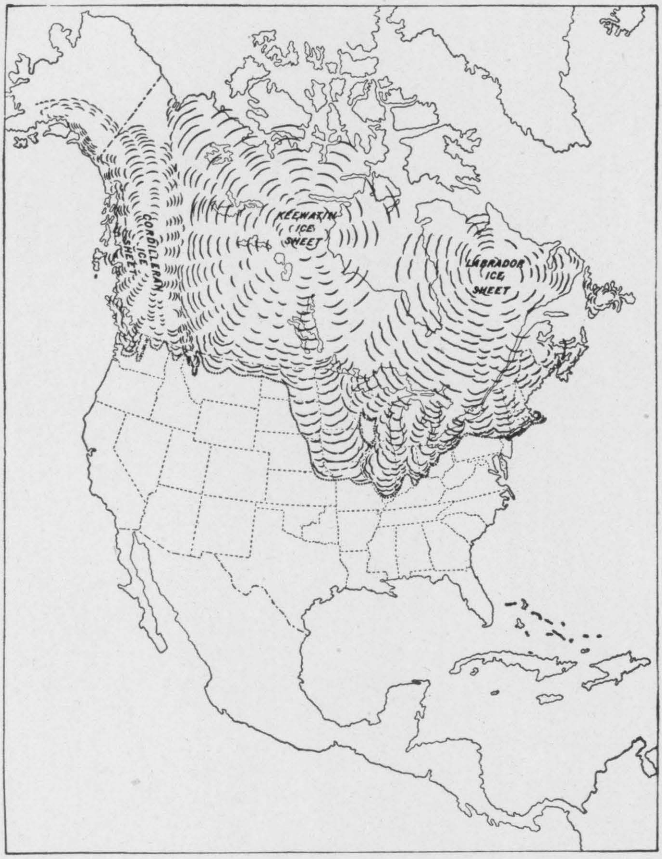
Where the bed-rock surface protrudes through the drift, the ledges are often seen to be scratched, striated, grooved, and sometimes highly polished, as if a heavy and somewhat rigid body had moved over their surfaces. The rock hills in the glaciated part of the country have smoother and more regular outlines than the hills farther south, and many of them have a more gentle slope on the north side than on the south, as if the agent which smoothed them had approached from the north. Not only are the shapes of the hills of this area characteristic, but the valleys are also peculiar in that those in the bed-rock have a broad, open U-shape, rather than the more nearly V-shape of young valleys made by stream erosion in areas not covered by drift.

INFERENCES FROM DEPOSITIONAL AND EROSIONAL FEATURES.

It is hard to conceive of anything other than an ice sheet forming any one of the above observed features within the area covered by drift, and it is impossible to conceive of any other agent bringing about this combination of features. Water, wind, and moving ice are the only agents known which are capable of transporting material such distances as much of the drift of this region has been carried. The distribution of the drift over both hills and valleys and its unsorted condition precludes streams as the agent responsible for its deposition. The bowlders of the drift are too large to have been transported by the winds. It is known, however, that a great ice sheet can and does bring about just such a series of results as have been described. For instance, a great ice sheet now covers the greater part of Greenland, and the surface around its edge, uncovered by the withdrawal of the ice, shows features exactly like those observed in the Wheaton quadrangle. It is now conceded by all geologists best qualified to judge that the northern part of North America was covered during the glacial period by an ice sheet similar to that which now lies over Greenland.

THE RECURRENCE OF ICE EPOCHS.

The data which have been collected in the glaciated area of North America show that this portion of the continent has been covered by ice more than once. In many places fresh, unaltered drift overlies drift whose materials have been greatly affected by weathering, and which therefore appears distinctly older than the material of the drift



Sketch map of North America, showing the area covered by the ice sheets during the glacial period. The dotted black line represents the approximate maximum extent of the ice. The centers from which the ice moved, and the general direction of the movement are also roughly shown. (U. S. Geol. Survey.)

above. In some cases, the lower body of drift has been colored red by oxidation of the iron contained in it, during exposure to the atmosphere, while the drift above remains uncolored. Peat beds and vegetal remains have been found between two drift sheets. Several inches or some feet of soil, lying where it was formed and containing leaves or parts of trees, are frequently found beneath one body of drift and above another. This is often the explanation of the finding of leaves, pieces of wood, etc., far below the surface when wells are dug or drilled.

From such data as these, the Pleistocene period has been divided by students of the geology of North America into distinct glacial epochs, separated by epochs during which the land was not covered by the ice. In the first epoch an ice sheet advanced from north to south, reached its maximum extent, and withdrew to the north. Then followed an epoch during which the surface was subject to the action of the atmosphere, and plants and animals lived upon it. In the next glacial epoch another ice sheet advanced, reached its maximum extent, and withdrew. This sequence was repeated until five ice sheets had advanced and withdrawn in succession. Not all of these left deposits in the area of the Wheaton quadrangle but all are known to have occupied the upper portion of the Mississippi valley as far south as Iowa.

CHAPTER III—GLACIATION OF THE WHEATON QUADRANGLE.

GLACIAL DEPOSITS OF THE DISTRICT.

Age of the Drift.

The great body of the drift which appears in this region was deposited in the last, or late Wisconsin, glacial epoch. Its materials are fresh and show no evidence of a long period of weathering. Few of the bowlders show signs of decay, and many of the limestone pebbles and bowlders, more easily destroyed than most of the other stony material, still retain

Figure 1. Map of the Great Lakes region showing the area covered by the late Wisconsin ice sheet. The heavy black line represents the maximum extent of the ice in this epoch. The x in northeastern Illinois gives the location of Wheaton.

the shallow scratches or striations made upon them while being moved by the ice. Moreover, the surface of the drift has been little changed from its original shape. The older drift sheets, as exposed in the southern part of Illinois and elsewhere, have been cut by streams into valley systems, thus destroying, or at least modifying, their original topography; but the configuration of the drift surface in the Wheaton area is, for the most part, very much as it was left by the ice. It has been little changed by stream erosion except in immediate proximity to the main drainage lines. The Wheaton district is within the area of the Wisconsin drift. (See fig. 1.)

Types of Drift.

In every drift sheet are different phases of drift, which, having been formed under more or less differing conditions, show different characteristics, and are given different names. The *terminal moraine* is that part of the drift which was deposited at the edge of the ice sheet while the edge was stationary. It is usually thicker and has a more uneven surface than the main body of the drift. The remainder of the drift, deposited beneath the ice, is known as *ground moraine*. These two phases of drift are essentially *unstratified*. The drift deposited beyond the edge of the ice by the waters resulting from its melting is *stratified*. Where it is spread out flat, it constitutes an *outwash plain*. Where it was deposited in the bottom of a valley through which the depositing stream flowed, it forms a *valley train*. A *kame* is a hillock of stratified drift, and an *esker* is a ridge of similar material.

These various phrases of drift as shown in this area, are discussed in the order of their importance.

The Terminal Moraine.

DISTRIBUTION.

The terminal moraine of the Wheaton quadrangle occupies a fairly well-defined but irregular belt in the western half of the area (Pl. II). Its trend is, in general, north and south. Starting at the north edge of the area just west of the village of Bartlett in Cook county, it extends south and a trifle east to West Chicago, thence in a nearly southeast direction through the village of Warrenville, and beyond, toward Naperville. Two and a half miles north of Naperville the belt loses its terminal moraine characteristics and grades into typical ground moraine.

The belt varies in width from 1 mile, a little southeast of West Chicago, to 2½ miles southeast of Bartlett and east of the villages of Wayne and Warrenville. At West Chicago it is hardly 1½ miles broad. It is connected with ground moraine on both sides and grades into ground moraine at the south end. In many places the line between ground and terminal moraine is fairly well defined, but in others it is indefinite, and its location on the map is more or less arbitrary.

The borders of the terminal moraine are not, on the whole, more definite on the one side than on the other. At the north, the boundaries on both sides are somewhat indefinite. For 3 miles north of West Chicago, the eastern border is somewhat more defined than the western, but a little farther south the reverse is true. That there is ground moraine both to the east and west of the terminal moraine is due to the fact that the terminal moraine was deposited at the edge of the ice after it had receded from its position of greatest advance.

RELIEF.

In general the terminal moraine is a ridge standing somewhat above its surroundings. Its highest point in this quadrangle is in the SE. 1/4 sec. 33, Hanover township, Cook county. The top of the ridge at this place is more than 880 feet above sea level. From this elevation there is a drop to the east of 50 feet in a quarter of a mile, which is rather more than its average slope. The average elevation of the crest of the ridge is between 780 and 800 feet, some 20-30 feet higher than the surface of the ground moraine to the east, and 30-40 feet above its surface to the west. North of West Chicago and elsewhere there is a vertical range of about 20 feet between the tops of the elevations and the bottoms of the depressions. There are also many places in the ground moraine where the relief is as much as 20 feet, but the lowest and highest points are farther apart horizontally, and hence slopes on its surface are not so steep as those on the surface of the terminal moraine.

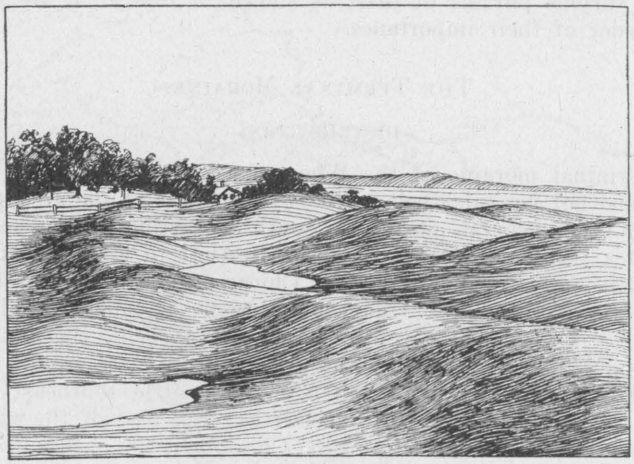


Figure 2. Sketch showing characteristic terminal moraine topography.

TOPOGRAPHY.

Any well developed terminal moraine has a perfectly characteristic topography. Such a topography is made up of sharp knolls or knobs associated with small irregular depressions having steep slopes and small bottoms. The elevations and depressions show no order in their relations to one another, but are scattered over the surface without any definite arrangement. The most characteristic feature of a typical moraine topography is the abruptness of all the elevations and depressions, and the general steepness of their slopes; that is, the surface is more than ordinarily rough in a small way (fig. 2).

The topography of the terminal moraine as mapped in the Wheaton quadrangle is by no means everywhere that characteristic of a well developed terminal moraine. The area mapped as terminal moraine includes much drift which has a topography characteristic of ground moraine, but as a whole the belt shows, in rather feeble expression, topographic features characteristic of terminal moraines. This topography is well shown, (1) 2 miles west and a little south of the village of Bartlett, in sec. 4, Wayne township, and secs. 32 and 33, Hanover township; (2) 1 mile east and for 1 mile north of West Chicago; (3) along the line between sec. 31, Milton township, and sec. 36, Winfield township; and (4) 1½ miles north of Warrenville, in sec. 26, Winfield township. While similar topography appears in numerous other places in the belt, the terminal morainic features are shown better in these four places than elsewhere, and these are the places which should be visited, if a distinct conception of terminal moraine topography is sought. (See Pl. III, *A*.)

(1). The roughest part of the whole area is west of Bartlett, where the surface is very irregular in a small way. The elevations are knobs or knolls, and the depressions are small, relatively deep, and well-defined isolated hollows that are, for the most part, undrained. The elevations and depressions have no orderly arrangement with respect to each other but are associated in apparent confusion; and there are no flat areas of any considerable size.

(2). The topography east of West Chicago is that of a weak terminal moraine. It consists of undrained depressions, nearly all of which contain small ponds and low, but well-marked, knolls. Loveless lake occupies one of the larger undrained depressions.

(3). At the middle of the line common to sec. 31, Milton township, and sec. 36, Winfield township, terminal moraine topography is well developed. The relief is not great and the surface is not conspicuously rough, but it is distinctive. The depressions are numerous and irregularly arranged, and most of them contain definite water bodies. Between the depressions are many low knolls, most of them small and evenly rounded. Here also there is no regularity of arrangement among elevations and depressions. They bear all relations to one another, and have no definite relation to streams or stream valleys.

(4). In sec. 26, Winfield township, occurs some of the most characteristic terminal moraine topography in the area. The elevations are close together, are more or less symmetrical in shape, and have steep slopes. The relief is about 40 feet (Pl. III, *A*.)

If a depression on the surface of the drift has no outlet, and is deep enough and small enough to have abrupt slopes, it is known as a "kettle hole" or simply as a "kettle." Kettles are much more frequent in terminal moraines than in ground moraines.

Few of the depressions of the terminal moraine in this region can be cited as striking kettles. One of the best is in the SE. 1/4 of the NE. 1/4 of sec. 23, Wayne township, on the east side of the north-south road. It is nearly circular, and its sides slope rather uniformly toward the center. It is about 250 feet in diameter, and 10-15 feet deep. Except for this kettle the topography here is like that of a ground moraine. Another kettle-like depression occurs three-fourths mile south-east of West Chicago, in the south central part of sec. 10. It is simply a more than usually abrupt basin, having a diameter of about 100 yards and a depth of about 15 feet. It contains standing water during most of the year. A distinct kettle exists also in the extreme west central part of sec. 32, Milton township, on the eastern edge of the terminal moraine. It is about 300 by 150 feet in area, and 30 feet deep. Most of the undrained depressions of the moraines are saucer-shaped, rather than kettle-shaped.

The formation of kettle-like depressions in the terminal moraine was undoubtedly connected with the edge of the ice sheet. They may have been formed in several ways. (1) At the edges of present glaciers the ice is sometimes broken up into blocks. It is conceived that such blocks, detached from the edge of the ice sheet, might be buried in the drift which the ice was depositing. After the recession of the edge of the ice, the melting of these buried blocks would let the overlying drift down, thus forming a depression. (2) Depressions might also be formed by a crossing and recrossing of subordinate terminal morainic

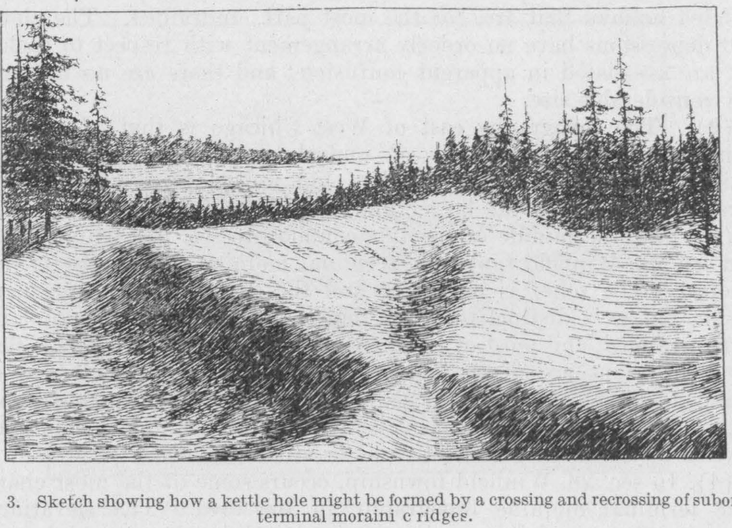


Figure 3. Sketch showing how a kettle hole might be formed by a crossing and recrossing of subordinate terminal morainic ridges.

ridges (fig. 3). The ice edge probably oscillated back and forth unevenly along its course, and tended to deposit ridges of drift under its edge at various points. These minor ridges might cross each other at various angles leaving depressions between. (3) Some parts of the

A. The terminal moraine, 1½ miles north of Naperville.

B. Section of till in the terminal moraine, 1½ miles north of Warrenville.

edge of the ice undoubtedly had more drift than others. Less material was therefore left on some spots than on the surrounding area. Any of these three processes or a combination of them would give rise to kettles, but the last is probably the most important.

SEPARATION FROM GROUND MORAINE.

On the whole, the surface of the terminal moraine is somewhat rougher than the surface of the main body of the drift. Its knolls, hills, and ridges are more numerous, higher, steeper, and smaller in area than those of the ground moraine; its depressions are smaller, more clearly defined, and in general deeper. This does not mean that all parts of the surface mapped as terminal moraine are rougher than any part mapped as ground moraine. The rougher parts of the ground moraine are more uneven than the less-rough parts of the terminal moraine and there are spots where the surface of the ground moraine is as uneven as much of the terminal moraine. In spite of all exceptions, however, the surface of the terminal moraine is more uneven than that of the ground moraine, and the line between ground moraine and terminal moraine as located by the difference in topography alone, is in many places, a definite one. A few illustrative localities are specified.

(1) The surface of the drift in the extreme western part of Bartlett is distinctly different from that farther east in the village and beyond. At the east edge of the cemetery there is a distinct north-south line, to the east of which is low, gently rolling ground composed of broad, gentle swells and wide, low-lying, ill-defined depressions. To the west there is higher ground with greater relief, sharper elevations, and deeper and better defined depressions. This line can be followed even where the terminal moraine topography is not strong.

(2) Just east of the west line of sec. 30 in Milton township, the land is rougher and has greater relief than that further east. The elevations have the form of slight, ill-defined knobs, in place of the broad, gentle swells to the east. West of the line referred to, the topography can hardly be said to be characteristic of a terminal moraine, as the elevations are slight and do not stand conspicuously above their surroundings; yet there is a distinct difference between this topography and that to the east.

(3) Three-quarters of a mile west of Winfield, the topography makes an abrupt and very noticeable change. For a half mile west of the river the land is low and only gently rolling, with broad, flat marshy tracts, and broad, gentle swells. Beyond this, however, the land rises rather abruptly, and a distinct line at right angles to the ascent can be easily traced to the north and south. This line is the division between the ground moraine and the terminal moraine. West of the line, the topography has distinct terminal morainic features. The elevations are more numerous and more abrupt, and on the whole the surface is rougher and more broken than to the east. But the feature which here marks the dividing line best is the distinct rise. When one is on the

ridge the change in topography is noticeable, but it is the rise of the terminal moraine above the surface to the east which first attracts attention.

The difference between the topography of the terminal moraine and that of the adjacent ground moraine is greater on the west side of the terminal moraine than on the east side, but its western boundary is not necessarily more easily located. In some places the rougher surface of the terminal moraine gives place gradually to the lower, planer surface of the ground moraine to the west, but in other places the junction of the two is distinct.

(4) For 2½ miles north of Warrenville the western margin of the terminal moraine is definite. The terminal moraine is noticeably higher and rougher than the land to the west, and a line separating it from the drift to the west can be drawn without difficulty. But in some other places, as for instance for a few miles north of West Chicago, the change in topography is so gradual that the line which separates the two phases of drift is not easily located, and might almost as well be drawn farther to the east or to the west of its position as represented on the map.

CONSTITUTION.

The material of which the terminal moraine is composed is shown by numerous cuts made for roads, railroads, gravel pits, house foundations, etc. Some data are also afforded by wells which have been dug or drilled into the drift. A very large portion of the terminal moraine is made up of a heterogenous mixture of yellowish or grayish clay particles, sand grains, pebbles, and bowlders. (Pl. III, *B*.) The greater part of this material is the same as that making up the ground moraine. It is known as till. Mixed with the till is a noticeable amount of assorted or partly assorted sand and gravel. The unstratified material appears most often in the road and railroad cuts and the stratified materials in gravel and sand pits, which have been located where these materials occur. The wells record both types. A few typical exposures of the till are described below.

In the railroad cut one-fourth mile east of Munger, in sec. 9, Wayne township, on both sides of the Illinois Central tracks, the till consists of an unsorted mixture of sand, clay, pebbles, and bowlders of different sizes and shapes under a layer of 2 or 3 feet of brown loam. The stony matter in the till varies in size from very small bits to pieces as large as an orange or larger. Probably 90 per cent of the stony matter is limestone, and the rest is granite, diabase, and shale. The fragments are angular or sub-angular rather than well rounded. The whole mass has a dull yellowish color from the clay, which is its chief constituent.

In the SE. ¼ sec. 10, Wayne township, is an abandoned pit on the east edge of the terminal morainic ridge, where the land rises abruptly from the bottom of the valley of the West Branch of Dupage river to the crest of the ridge to the west. The material here is unstratified, the stony matter being scattered through the clay without order. This exposure contains numerous bowlders. In the center of the pit is a pile of stones averaging about 1 foot in diameter, though among them are bowlders more than twice this size.

Similar material is exposed in a shallow cut three-fourths mile southeast of West Chicago, where the clay was formerly used for making brick. Another typical exposure occurs along the tracks of the Aurora, Elgin and Chicago Electric Railway, at Ingalton. Others may be seen in nearly every road and railway cut, and the same sort of material is taken from nearly every post hole and ditch. Typical till may be discovered at most places on the terminal moraine, 3 feet or so below the surface.

The stratified and the unstratified till lie in all possible relations to one another. Gravel is more abundant than sand, but it shows only a very rough sorting, being in marked contrast to the sands and gravels of the outwash, which will be described later.

At the junction of secs. 10 and 11, Winfield township, and three-fourths mile east of West Chicago there are three pits in till, which is much more gravelly than most till. A half mile south of this is a large pit in roughly stratified material. The bowlders run up to 1½ feet in diameter, and cobbles 6, 8, or 10 inches in diameter are very common. There is also some sand in this cut, though it is only roughly separated from the gravel.

In secs. 32 and 33, Hanover township and sec. 4, Wayne township, 2 miles southwest of Bartlett a series of small gravel pits show material which is roughly stratified. The gravel is in poorly defined areas or pockets rather than in definite layers, and these pockets are associated with irregular areas of till. The cobbles of the gravel average about 6 inches in diameter. Pl. IV, *A*, gives an idea of the appearance of the drift at this place.

In the central part of sec. 21, Wayne township, a pit 15 feet deep exposes both till and gravel. The main part, that on top, is typical till containing many large bowlders. Underneath this are 4 feet of laminated silts with some gravel. Many large bowlders are associated with the till. This is a good place at which to study the differences between the stratified and the unstratified parts of the terminal moraine.

The wells drilled in the terminal moraine show that it is made up of till, sands, and gravels. Some wells report more of the stratified materials than of the till, and others report the reverse. Five records of wells in the terminal moraine read as follows:

Well records in the terminal moraine area.

Well No.	Material.	Thickness.
		Feet.
17	Clay (till), gravel, rock	170
23	Mostly sand, no rock	130
21	Sand, gravel, clay (till)	140
19	Clay (till)	100
16	Gravel	60
	Clay (till)	11
	Sand	20

SURFACE BOWLDERS.

Bowlders of greater or less size often occur on the surface of the terminal moraine, though they are not so numerous here as on the terminal moraines of many other regions. In fact they are as numerous on the surface of the ground moraine in some regions as on the terminal moraine of this area. It is noticeable that the bowlders are most abundant where the terminal moraine topography is best developed, hence they are most conspicuous in the area east and north of West Chicago, where the topography has a particularly knobby appearance. On one elevation here 7 bowlders were counted in a straight line in a distance of 150 feet. On the terminal moraines of some regions surface bowlders are so close together that one can walk for considerable distances without stepping from them.

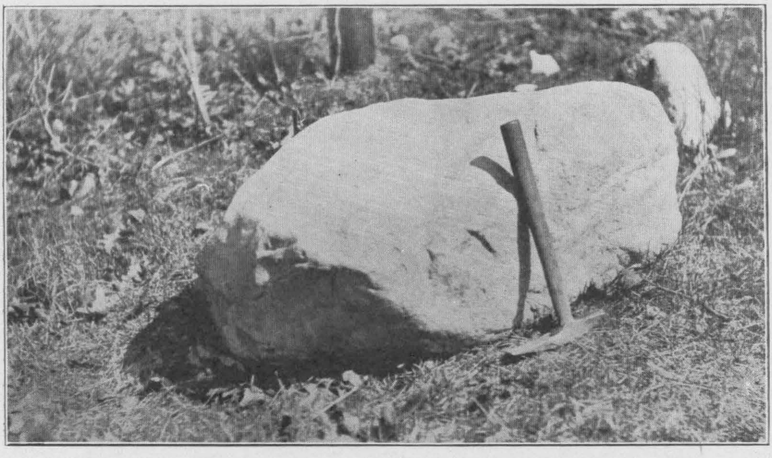
The bowlders vary in size from those as large as a man's head to those 2 feet or more in diameter. They are, as a rule, well worn, indicating that they were transported great distances by the ice. Nine out of ten of them are of igneous or metamorphic rocks entirely foreign to this region. They consist of diorites, gabbros, granites, granite-gneisses, schists, and occasionally limestone. The large percentage of foreign material shows that the bowlders came from a part of the ice where the local material was very subordinate. Probably its upper part, in overriding the higher lands of crystalline rock to the north, plucked fragments from the hill-tops. These fragments got into the upper part of the ice sheet and in this position were carried far from their sources. The surface from which the local limestone bowlders of the drift were derived was a rather low and not very rough plain, as shown by the well records above; and consequently the pieces which were plucked from its surface would not have the same chance to get into the upper portion of the ice. The bowlders from a distance were deposited at the edge of the ice sheet, where it melted from under them, hence their greater abundance on the terminal moraine where the edge of the ice stood long. A bowlder of limestone is shown in Pl. IV, *B*. Its top surface is striated but the striations can not be seen in the photograph.

THICKNESS.

The greatest thickness of drift in the terminal moraine as found from well records is 144 feet. This occurs in the SE. 1/4 sec. 23, Winfield township (17). There is another record of 140 feet in the north central part of sec. 15 (21), and one of 125 feet in sec. 14 of the same township (20). The thinnest drift recorded in the belt is 100 feet, in sec. 23, Winfield township.

The average thickness, shown by the five wells which go down to rock (17, 18, 19, 20, 21), is 122 feet. This is but little more than the average for the region as a whole, and not more than the average thickness of the ground moraine to the east.

A. Stratified material in the terminal moraine, northwest part of section 4, Wayne township.



B. Bowlder of limestone on the surface of the terminal moraine.

MANNER OF DEPOSITION.

The materials of the terminal moraine were deposited under the edge of the ice sheet while it was stationary or nearly so. Ice was constantly advancing to the edge, bringing with it the materials which it had picked up from the surface over which it had come. The ice melted at the edge about as fast as it advanced, and the material was of necessity dropped (fig. 4). The larger, unstratified portion was deposited by the ice itself without aid from the associated waters. It was deposited without assortment or arrangement of the materials, thus forming the till. The sands and gravels, however, were washed out from the rest of the drift (or the clay was washed out from them) and deposited by the water which resulted from the melting ice at or near the edge of the sheet. This water mostly ran off to the west from the edge of the ice. The materials carried by it were sorted, the coarser and heavier parts falling first and near the ice edge, and the finer and lighter parts later and farther away. There were also basins about the edge of the ice in which materials were deposited as deltas. As the edge of the ice oscillated slightly, and the drift material kept coming in, the sites of deposition doubtless changed so that till was sometimes deposited where the stratified materials had been left previously; or basins were formed and stratified materials were deposited where the ice had previously deposited till. Thus the sands and gravels may be found within, under, or on top of the till.

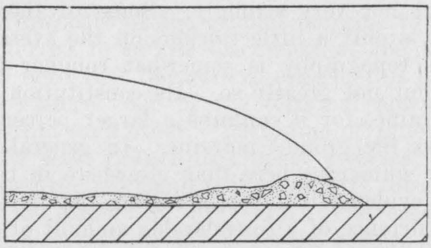


Figure 4. Diagram showing the relation of the terminal moraine to the ice and to the ground moraine. It is deposited under the edge of the ice.

The rough surface of the terminal moraine is due partly to the oscillation of the edge of the ice, partly to the unequal deposition of the material, and partly to deposition by waters in reentrants in the edge of the ice. The methods by which the surface is made irregular by the formation of subordinate terminal morainic ridges and by variation in amount of material dropped at the edge of the ice has been discussed above (p. 32). Further, the unevenness of the morainic surface may be due to the fact that the edge of the ice was made irregular by the breaking off of blocks, or by the differences in the rate of melting and of ice movement. If the ice melted faster at one point along its edge than on either side, though the ice advanced at the same rate at all points, a reentrant was developed where the melting took place most rapidly. Materials were deposited in these reentrants and cracks, both by the advancing ice and by the waters resulting from its melting. This material filled the cracks and lay against their edges and when the ice melted back it slumped down into the form of irregular hills or knobs. In these three ways at least, the surface of the terminal moraine is made irregular.

SUMMARY.

It may be again pointed out that the terminal moraine of this region is only a weak representative of its class. There are several criteria for distinguishing a terminal moraine from other parts of the drift. (1) The drift of a terminal moraine is generally thicker than that of the main body of a drift sheet. (2) Its topography is generally rougher than that of the ground moraine. Its elevations should be knobs rather than swells, and its depressions should approach the kettle type. (3) It generally contains more stratified material than the ground moraine. (4) Surface bowlders are more numerous on a terminal moraine than elsewhere on the surface of the drift. (5) It should be bordered, in places at least, by outwash material on the side toward which the ice moved. If a belt of drift shows these characteristics to a very slight degree only, but lies between areas that are unquestionably covered by a terminal moraine, it is probable that the poorly characterized belt is also a terminal moraine.

The drift of the terminal moraine in this area shows most of these characteristics, but not very strongly. Some of them are not recognizable at all. It is only a little thicker, on the average, than the rest of the drift. Its topography is somewhat rougher than that of the ground moraine, but not greatly so. Its constitution, however, is that of a terminal moraine, for it contains a larger percentage of stratified material than does the ground moraine. In general also, the surface bowlders are more numerous here than elsewhere in the region. Probably the strongest evidence in favor of calling the drift ridge a terminal moraine is the occurrence of a considerable amount of outwash material along its western border. The outwash is not plentiful, but it is sufficient to match the feeble character of the terminal moraine. Moreover, the rougher and higher parts of the drift surface are distributed in a more or less distinct belt from the north edge of the area south to within 2 miles of Naperville. South and east of Naperville there is an extraordinary amount of stratified material in the drift, although all other features are those characteristic of ground moraine; and south of the DesPlaines river, at Mount Forest Island and Palos Park, there is a terminal moraine belt having about the same trend as the one in our area, but not continuing definitely to the north. The stratified material around Naperville suggests a connection between these two moraines, as made by Leverett.[1]

[1] Mon. U. S. Geological Survey, Vol. 38, 1899. map opp. p. 24.

The Ground Moraine.

Except for the strip or belt of terminal moraine, and some small areas of kames, eskers, outwash materials, bed-rock, etc., the whole area of the Wheaton quadrangle is covered with ground moraine. But there are two distinct phases of ground moraine, one lying to the east of the terminal moraine and the other west of it.

THE GROUND MORAINE EAST OF THE TERMINAL MORAINE.

Distribution.

Nearly all that part of the quadrangle which lies east of the terminal moraine, including nearly two-thirds of its total area, is covered by ground moraine. Its continuity is interrupted only by the kames north of Naperville, east of Glen Ellyn, and in the vicinity of Bloomingdale, and by discontinuous outwash material in the lower valley of the East Branch of Dupage river.

The feature of its distribution to be emphasized is its approximate universality. It does not occur in a belt like the terminal moraine, nor in small indefinite areas like outwash, nor yet as patches like the kames; but it is spread generally over the region. This is entirely compatible with its manner of deposition. The ice covered the whole region, and hence the material deposited beneath it should cover the whole region except where special conditions determined the deposition of other phases of drift.

The relation of this part of the ground moraine to the terminal moraine has been referred to in the discussion of the terminal moraine. It may be repeated here, that the western edge of this part of the ground moraine, and the eastern edge of the terminal moraine meet and in some places grade into each other. Their line of junction follows along the west side of the West Branch of Dupage river as far south as Winfield, where it crosses the river and swings slightly toward the east in the general direction of Naperville (Pl. II). The eastern edge of this ground moraine lies several miles beyond the eastern edge of the quadrangle.

Topography.

The surface of the eastern ground moraine is a rolling plain with no land which is really flat, nor which could be called rough. Its only especially noticeable topographic feature is the valley of the East Branch of Dupage river which is about 50 feet deep. The slopes and most of the bottom of the valley are parts of the ground moraine, and are so mapped. The valley is simply an elongated depression in the ground moraine which has been appropriated by the stream which now occupies it.

Just as the terminal moraine contains some land which has the topography of the ground moraine, so the ground moraine shows terminal morainic characteristics in some places. Locally the swells of the ground moraine come closer together than is their wont and become a little more abrupt and knoll-like, while the depressions become smaller and better defined. Topography which aproaches that of a terminal moraine appears in the southern part of sec. 7, and the northern part of sec. 18, Milton township, in the east central part of sec. 1, Lisle township, and in the northwestern part of sec. 13, Bloomingdale township. In none of these places is there more than a suggestion of terminal moraine topography, though the surface is slightly rougher and more hummocky than over most of the region. The patches where this topography prevails are relatively rare and they are not connected with each other, as are the rougher parts of the terminal morainic ridge.

The topography of this portion of the ground moraine may be divided into two types: the *undulatory type* and the *flat type,* although much of its surface shows gradations between the two types. Probably 99 per cent of the surface belongs to the undulatory type. The flat type occurs in very small areas only, and grades into the undulatory type on all sides.

The *undulatory type* of topography is made up of gentle swells and broad, open, irregular depressions. The elevations take the form of low, rounded hills, or broad, poorly defined ridges. They vary in size from a few hundred feet to one-half mile in diameter at the base, and in height from 5 to 40 feet. Their slopes are seldom more than 40 feet in one-fourth mile, and more commonly only 10 to 20 feet. The steepest slopes occur on or near the sides of the valley of the East Branch Dupage river, where they are locally as steep as 60 feet to one-fourth mile. The depressions are broad, somewhat poorly defined swales, lying among the elevations. Nearly all of them contain standing water after rains, and many of them have marshes or ponds permanently. They are for the most part undrained, though some of them have been drained out by the erosion of running water. (Pl. V, *A.*)

The country in and immediately around Wheaton furnishes an illustration of this type of topography. In the city itself the surface is somewhat less undulatory than in the suroundings, but even here the streets are scarcely level and the larger lawns show minor irregularities. Wheaton College stands on one of the greater elevations, about 20 feet above Water Street. The Wheaton Hotel and the water-works buildings occupy one of the depressions a few feet lower than Water Street. On the road leading out of town the typical ground moraine topography is well shown. For instance the road leading northwest and west past Jewell Cemetery, passes over low elevations and across low-lying swamp land, with only short stretches of level surface. The road north to the Driving Park shows similar topography. The race track itself occupies a gentle depression, but even here the surface is not perfectly level. A cut was made on its east side, and fills were made in several places before a level track was secured. The surface between Wheaton and Glen Ellyn is also typical of ground moraine topography. It gets gradually rougher and higher toward Glen Ellyn and assumes a distinctly undulatory appearance. The area east of Glen Ellyn, however, is of a different nature. This will be referred to later.

A. A typical view of the ground moraine east of the terminal moraine. View 3½ miles south of Wheaton.

B. Cut in till along the A. E. & C. Electric railway, 1 mile northwest of Wheaton.

At Downers Grove the surface is rougher than around Wheaton. Stream erosion has had some slight effect on the topography here, but for the most part the surface is that of the unaltered ground moraine. The village water-supply committee took advantage of the undulations of the surface in planning the water-works. The wells were bored in one of the depressions at the north edge of town where the drift is probably thinnest, and the stand-pipe is located on an elevation in the south edge of town, where the most pressure can be secured.

The *flat type* of ground moraine topography appears in some small areas surrounded by the undulatory type. It is best seen along the Naperville road south of Wheaton. Along this road through the central part of sec. 21 to the center of sec. 28, Milton township, the topography is typical for ground moraine. For two-thirds of the way through sec. 21 the land is gently rolling, with broad gentle swells having average slopes of about 30 feet per mile, and low, nearly flat-bottomed depressions. Ponds and marshes are not infrequent. But in the southern part of sec. 21, and extending through sec. 28, the topography is flatter. Here, there are small undrained depressions, but they are so shallow that they can hardly be seen except when they contain a little standing water. The maximum relief is not more than 3 or 4 feet.

The village of Lombard is situated in this flatter topography, which extends thence east and northeast to the edge of the area. It is best shown along the road in the central part of sec. 5, York township, where the surface is almost level, and shows only low, indistinct swells and sags to distinguish it from a lake or river flat. It has a relief of not over 10 feet in a mile.

North of Itasca as far as the north side of the southern tier of sections in Cook county, the topography should be classed with the flat type of ground moraine. The relief is hardly 10 feet, but the swells are clear and the sags definite. Ponds and small marshes are very common, but there are no sharp rises or descents. Depressions give place to elevations along very gentle, hardly noticeable slopes.

Along the East Branch of Dupage river the slopes are so much steeper than the rest of the surface of the ground moraine, and the river is so much lower, that its valley constitutes a noticeable feature in the landscape. A characteristic cross section of the valley is that east of Naperville. From Naperville one passes over the rolling plain of the ground moraine to the valley, then down 60 feet, and across one-half mile of low, rolling land similar to that described above, and then up the steep eastern slope for 60 feet, and out onto the plain to the east. The valley is shallower and narrower to the north and finally ceases to be a distinct topographic feature east of Bloomingdale.

The east and west slopes of the valley are in most places rather abrupt, but more so to the south than to the north. East of Naperville there is a descent from the plain to the valley bottom amounting to 60 feet in one-eighth mile, which is the steepest slope observed in the region.

The bottom of the valley is much like the surface of the plain above, its most marked difference being that of elevation. Its topography, for the most part, is gently rolling. Bordering the stream there are some narrow strips that are perfectly flat, but they are too small to produce any noticeable effect in the general appearance of the valley bottom.

The surface east of the terminal moraine is thus not very markedly unlike that of the terminal moraine itself, except that it is less uneven. Its surface, in general, is not quite so high as that of the terminal moraine nor is it so knobby. The line between the ground moraine and the terminal moraine is commonly definite though not always so.

Constitution.

Much the greater part of the material mapped as ground moraine is till, but there are also some stratified sands and gravels associated with it. Both stratified and unstratified materials have been described briefly in the account of the terminal moraine. The unstratified drift is described again in a little more detail because it is the characteristic deposit of the ground moraine.

Till—The till is an irregular mixture of clay, sand, and gravel. Most of the material is stiff clay,—sticky when wet, and hard and stiff when dry. A fresh, wet surface is usually grayish blue. Weathered surfaces are dull yellow. The clay is the matrix of the till, and the stony matter is embedded irregularly in it. The toughness of the clay has earned for the till the name of "hardpan." (Pl. V, *B*.)

The stony matter is made up mostly of limestone, but comprises some sandstone, some diabase, and granite, and some bits of shale. These rocks are usually in small fragments. Most of the pieces are only about 1 inch or less in diameter, although bowlders up to 2 feet in diameter are not rare. The rock fragments are angular or subangular rather than rounded; that is, they are bounded by intersecting planes rather than by curved surfaces. On the whole, the igneous rocks are more rounded than the shales and limestones. This may be explained as due to the fact that they have been transported farther from their sources, or that they were more rounded when picked up by the ice.

The till is highly calcareous; that is, it contains a carbonate which efferveses strongly when touched by hydrochloric acid. This material is in the clay which forms the main body of the till, distributed in small pebbles of limestone and in small calcium carbonate concretions embedded in the clay.

Moreover, many of the fragments in the till are coated with a white deposit of calcium carbonate which was dissolved from the drift by water, and deposited on the surfaces of the rocks.

The till is exposed in many places in the area. It was particularly well exposed in Wheaton in the summer of 1907 during the progress of the extensive plan of street paving that was undertaken at that time. On College Avenue east of Wheaton College, the material underlying the soil or old street fillings is a hard, sticky, yellowish clay, containing many small, angular, glaciated bits of rock; and near the north end of Main Street a 5-foot cut for a cellar drain showed the same material. A little farther north on the east side of the race track at the Wheaton Driving Park a shallow cut 100 yards in length exposed material composed of clay, with pieces of limestone and some igneous rock intermixed. The plumbers of Wheaton say that this "hard pan" occurs almost uniformly immediately under the soil north of the railroad tracks, but that there is more gravel at the surface in the south part of the city. The only exception noted was on College Avenue where a thick bed of gravel was reported to lie 18 inches below the surface. Though most of the surface material in Wheaton is till, it does not in all places extend down to the rock surface beneath, for some well borings started in the till have penetrated sands and gravels.

Till also underlies Downers Grove, Lombard, Roselle, Naperville, Itasca, and Glen Ellyn. In the north part of Glen Ellyn there are great thicknesses of till with little or no gravel or sand. A ditch here showed 4 feet of bluish till under 6 inches of brown loam. At Staceys Corners a well records 112 feet of clay containing pebbles, the yellow clay on top grading into blue clay farther down. There seems to be no gravel at all here. In Itasca, the wells are sunk through varying thicknesses of blue clay to gravel in which water is obtained. In one place 52 feet of blue clay was penetrated before gravel was encountered. The drift is exposed in several places in Roselle. In the northwest end of the village is located an abandoned brick kiln and clay pit where the pebbles are not very plentiful, and the clay is pure enough to make rough brick. Many exposures of till are seen in Naperville. About 15 feet of it are exposed where the Burlington railroad cuts through a low elevation near the cemetery. Several cuts in this material were also seen on the college campus.

Besides the places cited, there are many others where the till of the eastern ground moraine is exposed. It can be seen at nearly every road cut and along nearly every stream bank. Along roads where new telephone poles or fence posts have been put in recently, little piles of till have been thrown out. Every ditch for field tiling strikes till; nearly every house foundation is laid in it; and nearly all wells are dug in it. The till is by far the most common material in the region.

Sands and Gravels—The stratified materials in the ground moraine are not nearly so plentiful as the till. In the lower part of the East Branch Dupage river valley and in the upper part of the valley of the West Branch there are some sands and gravels which have a history slightly different from that of the stratified materials of the terminal moraine. These will be discussed later under the heading "outwash materials."

The ordinary stratified materials of the ground moraine, like those of the terminal moraine, occur in pockets and discontinuous layers in the till. They appear at the surface on top of the till in many places, but are more commonly encountered in wells. Where seen, they are usually under elevations rather than under depressions. This does not necessarily mean that they are more common under elevations than elsewhere. It may be merely because only the elevations are opened for gravel pits that the gravel is made to seem more abundant in this position.

There appears to be no law governing the distribution of the stratified materials. They appear in different parts of the ground moraine, but not more frequently in any one part than in any other. In going through the region, one is likely to come upon a pit or other exposure of this rough gravel almost anywhere. Its occurrence cannot be connected either with present or with pre-glacial drainage lines, nor with other topographic features. The gravel pockets simply occur without order through the till.

The character of these deposits can be indicated best by the description of a few typical exposures.

1. A half mile south of Wheaton there is a gravel pit 15 feet deep in stratified gravels and sands lying so loosely that they are readily shovelled. A large proportion of the stony matter is limestone, though an occasional bit of water-worn shale or an occasional bowlder of diabase or rotten granite occurs. It is notable and significant that the pieces of rock are not generally well rounded, but are rather angular or subangular like those of the till. (See Pl. VI, *A*.) This fact shows that they were shaped chiefly by the ice, without having been much changed by the water in which they were sorted out from the rest of the drift. A typical section for this pit shows at the top 2 feet of brown loam without stony matter, followed beneath by 2½ feet of very coarse sand, coarse and fine gravel with pebbles up to 6 inches in diameter, and 6 feet of intercalated and intermixed layers of pure gravel, nearly pure sand, very fine gravel, and mixtures of gravel and sand.

2. A little south of this pit gravel again appears in the north part of the Wheaton cemetery, and in a cultivated field on its north side. At the northeast corner of the cemetery a small area which has been graded slightly, shows an abundance of moderately fine gravel.

3. Further, in the central part of sec. 4, Lisle township, a small pit is located in coarse, roughly stratified material containing angular bowlders a foot or two in diameter. Certain parts of the deposit are stained red with iron oxide.

4. Figure 5 shows a section in a pit in the east central part of sec. 23, Milton township:

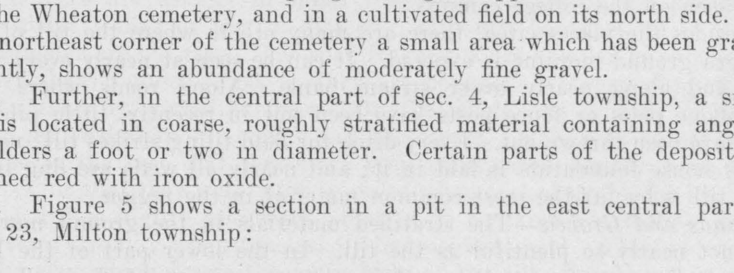
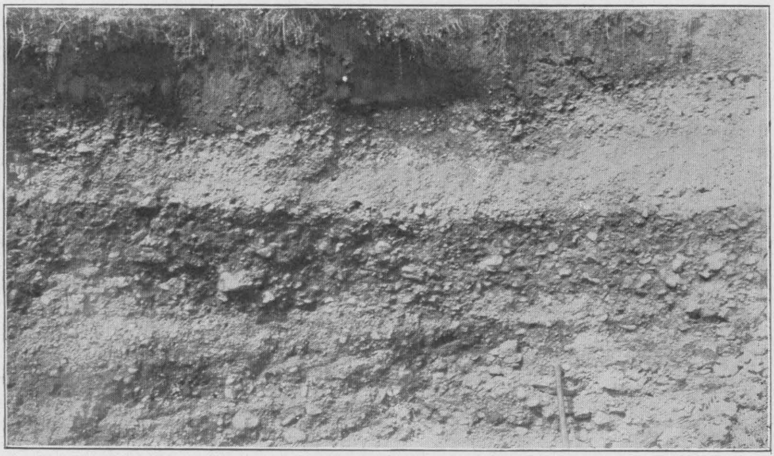


Figure 5. Section of a stratified portion of the ground moraine in a pit in sec. 23, Milton township.

A. Pocket of stratified material in the ground moraine, one-half mile south of Wheaton.



B. Section of the terrace at Lisle, showing stratified gravels.

Relation of the stratified materials to the till—The relative positions and amounts of the sand, gravel, and till can be brought out best from a study of the well records. About 50 are available for this study, but only a few of those which are the best authenticated and which show the relations best are given below. In the records, "clay" means till.

Records of shallow wells in the Wheaton quadrangle.

Well No.	Location of well.	Thickness of drift.	Character of material.
		Feet.	
70	Sec. 32, Addison township	50	Clay
		55	Fine clay
29	Bloomingdale	127	Clay with a little sand intermixed
50	Wheaton town wells	6-8	Surface soil
		12	Gravel, very fine to bowlders 10 in. in diameter (average ⅓ in.); some clay
		16	Sand and clay
		4-5	Yellow clay (hardpan)
		60	Blue clay; few inches of quicksand and gravel over limestone
25	Ontarioville	150	Clay and bowlders
72	Itasca	80	All clay
55	Sec. 22, Milton township	154	Some sand, mostly clay
71	Sec. 13, Bloomingdale township	70	A little sand 24 ft. from top
48	Sec. 9, Milton township	30	Yellow clay
		110	Blue clay with small pockets of gravel
26	Roselle	130	Clay
		12	Sand
50(c)	Wheaton	105	Surface soil; clay; sand 45-50 ft. from surface
49	1 mile east of Wheaton	80	All blue clay
61	Sec. 20, Downers Grove	120	Clay and gravel

Thickness.

The thickness of the ground moraine east of the terminal moraine can be estimated only from the records of wells which have been sunk through it. The bed-rock does not appear at the surface in this portion of the region, though it does at Elmhurst, 2 miles east of the eastern edge of the quadrangle. From the records of 44 wells which go down to rock it is estimated that the average thickness of drift over the eastern portion of the quadrangle is 126 feet. This is 4 feet more than the average thickness of the terminal moraine, calculated from the records of 5 wells in the area covered by this deposit.

The drift is thickest, so far as known, in Bloomingdale township. In sec. 22 (37), a depth of 171 feet is recorded; in sec. 28, 174 feet in one place (40) and 178 in another (39). The drift thins gradually to the east. In the southeast part of sec. 13 of the same township, 3 miles east and 2 miles north of the site of the thickest drift, a well (71) reached rock 70 feet from the surface; in Itasca (72) rock was struck 77 feet from the surface; and in Addison (just off the east edge of the area) at 87 feet. The drift is 90-105 feet thick in Wheaton (50, a, b, c), 100 feet thick at the Glen Ellyn village well (47), 160 feet at Bartlett (24), and about 100 feet at Downers Grove (63).

Explanation of the Ground Moraine.

With the various features of the eastern part of the ground moraine in mind, we may consider how these characteristics were produced.

Knowledge of many geological processes can be obtained only from their results. In this case we have before us the various features of the drift which we know to be due to glaciation. It remains for us to make use of these known features in order to ascertain how the ice produced them. We may also go out of this particular region and consider the studies which have been made of existing glaciers. It is when we can observe both processes and results, and use the two together, that we get the best conception of both. The work of glaciers has been observed very carefully in Switzerland, Greenland, our western mountains, and elsewhere, and the results of these observations have been given in various publications. The great glaciated area of North America has afforded excellent grounds for close observation of the results produced by glaciers of continental size. As a consequence we have a fairly clear conception of the way in which an ice sheet acquires and deposits drift.

As the great ice sheet advanced from the north, over-riding hills and valleys, it not only picked up the soil and loose rock which covered the surface, but the great weight of the ice enabled it to erode the bedrock by using the included debris as tools. As soon as a fragment was picked up or broken from the rock surface, it became a tool by which the moving ice was able to acquire more material. Thus an ice sheet gets its load for transportation. By rubbing against each other and being dragged along the rock surface, the fragments become polished, sometimes scratched or striated, sometimes grooved, and sometimes bruised. If they were not too hard, or if they remained in the ice long enough, they were ground to powder, technically known as rock flour, and popularly known as clay. The greater part of the ground moraine material in this region is clay, produced in this way.

Source of the clays—The clay of the till was made in two ways; (1) by the grinding up of shales and limestone which were not transported far, and (2) by the grinding up of harder rocks, such as granite, which were caried great distances. Most of the clay probably came from the grinding up of shales and limestones.

It is known from well records along the east and west sides of Lake Michigan that the basin of the lake was once occupied by a great mass of shales of Devonian age. (See fig. 6.) The ice moved into this area of weak rock, carrying with it many fragments of the harder rocks over which it had ridden north of the great lakes. These are ideal conditions for effective erosion. The ice gouged out the soft shales with relative rapidity, so that there must have been a large amount of shale in the ice south of the basin. Most of the shale picked up here was probably ground to powder so as to make up the great body of the clay in the till.

Some of the shale pieces, however, withstood the erosive action of the ice more or less successfully and retained their fragmentary charac-

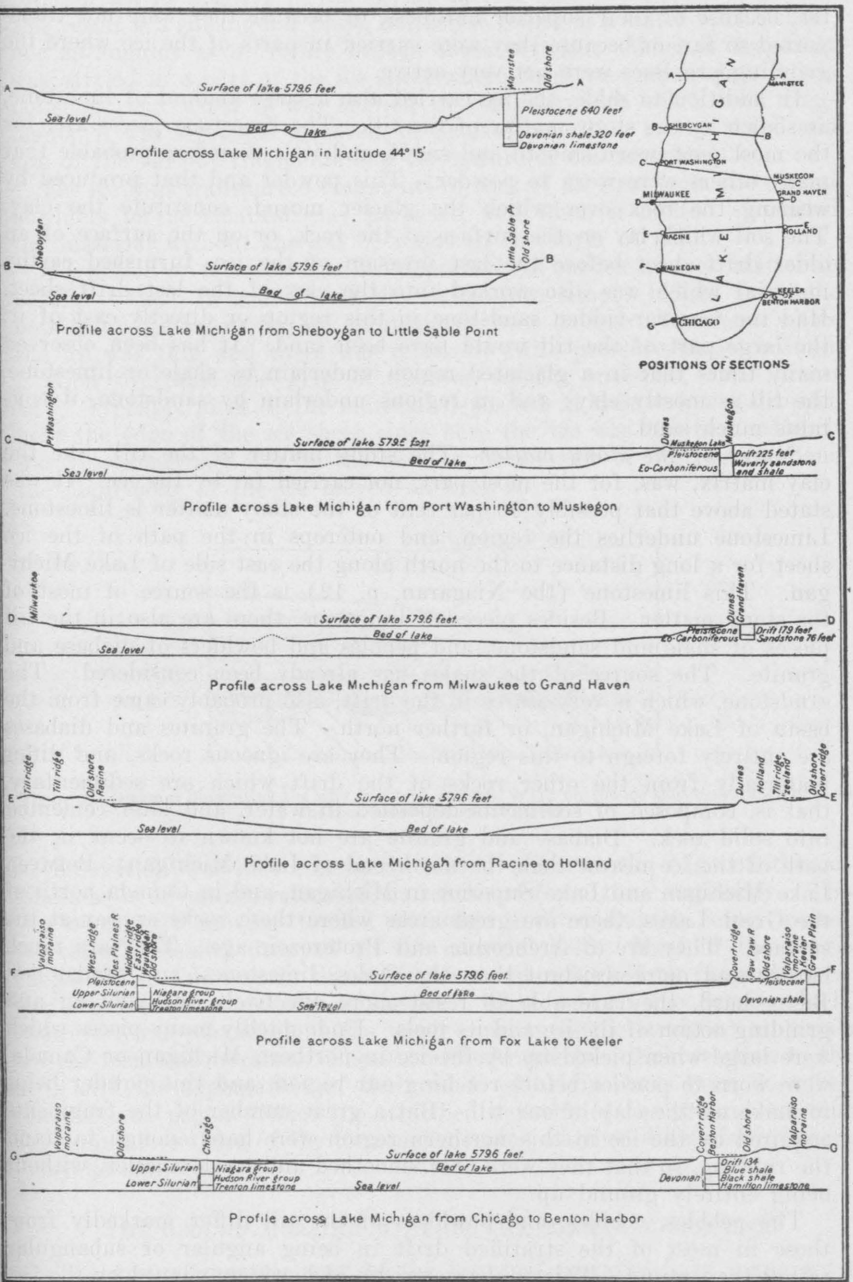


Figure 6. Diagrams showing the structure of the Lake Michigan basin. (After Leverett, U.S. Geol. Survey.)

ter, because of their superior hardness, or because they were not transported so far, or because they were carried in parts of the ice where the grinding processes were not very active.

In addition to shale, the ice carried also a large amount of limestone, as shown by the stony matter of the till. The limestone pieces are, for the most part, worn smooth and small, and it is therefore probable that many others were worn to powder. This powder and that produced by wearing the rock over which the glacier moved, constitute the clay. The soil which lay on the surface of the rock, or on the surface of an older drift sheet before the last invasion of the ice, furnished earthy material which was also worked into the clay of the last drift sheet. Had the ice over-ridden sandstone in this region or directly east of it, the large part of the till would have been sand. It has been observed many times that in a glaciated region underlain by shale or limestone, the till is mostly clay; and in regions underlain by sandstone, it contains much sand.

Source of the stony matter—The stony matter of the till, like the clay matrix, was, for the most part, not carried far by the ice. It was stated above that possibly 90 per cent of the stony matter is limestone. Limestone underlies the region, and outcrops in the path of the ice sheet for a long distance to the north along the east side of Lake Michigan. This limestone (the Niagaran, p. 12) is the source of most of the stony matter. Besides pieces of limestone, there are also in the till pieces of shale and sandstone, and pebbles and bowlders of diabase and granite. The source of the shales has already been considered. The sandstone, which is very scarce in the drift, also probably came from the basin of Lake Michigan, or farther north. The granites and diabases are entirely foreign to this region. They are igneous rocks, and differ materially from the other rocks of the drift which are sedimentary, that is, composed of sediments deposited in water, and later cemented into solid rock. Diabase and granite are not known to occur in the path of the ice nearer than the north end of Lake Michigan. Between Lake Michigan and Lake Superior in Michigan, and in Canada north of the Great Lakes, there are great areas where these rocks appear at the surface. They are of Archeozoic and Proterozoic age. They are much harder and more resistant than the shales, limestones, and sandstones. Being hard, they are able to resist more effectively the rubbing and grinding action of the ice and its tools. Undoubtedly many pieces which were large when picked up by the ice in northern Michigan or Canada, were worn to powder before reaching our region, and this powder helps to make up the clay of our till. But a great number of the fragments acquired by the ice in this northern region were hard enough to stand the rubbing, so that they were only smoothed and worn smaller, without being entirely ground up.

The pebbles, cobbles, and bowlders of the till differ markedly from those in most of the stratified drift in being angular or subangular rather than round. This is characteristic of bowlders shaped by the ice. In the bottom of the glacier the pieces of rock were imbedded in ice on all sides but one, and this side got most of the wear. As a piece of rock shifted its position in the ice, its various sides were worn to planes. The result is a subangular piece, neither as round as a water-worn pebble, nor as angular as a freshly broken mass of rock. When a fragment was carried in a part of the ice sheet where there was much clay, it was polished; and when it was carried in company with other rock fragments, it was scratched, grooved, or bruised, acording to the shape and size of the various fragments and the nature of the movement.

The ice thus transported fragments of rock of all sizes from the largest bowlders to the smallest clay particles, and when it melted, deposited the material without the aid of water in the form of till.

Deposition of the till—The ice deposited its burden of rock matter in various ways. In some cases the rocks were simply lodged from the bottom of the ice as the ice sheet moved over its bed. In places where the ice was thin and there was relatively little pressure on its bottom, friction overcame the grip of the ice on the material, and it was left. Probably most of the material deposited in this way was dropped near the edge of the ice sheet since here the ice was thinnest. Debris was also sometimes left on the lee—or down—side of obstructions, and the main body of the ice moved on over it.

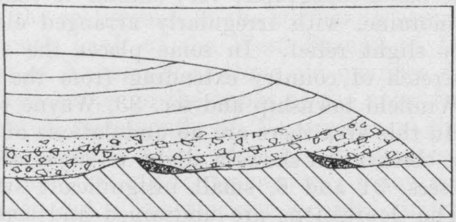


Figure 7. Diagram illustrating the way in which material is left on the lee side of protuberances on the rock surface beneath a glacier.

Deposition was also constantly taking place at the edge of the ice sheet as it advanced, retreated, or remained for a time stationary. The ice constantly moving toward the edge and constantly being melted there, of necessity dropped all the material held. Most of the debris deposited in this way in this region was not reworked by the waters resulting from the melting of the ice. That part of the debris which, however, was rehandled by the water constitutes the stratified materials of the terminal moraine. These stratified materials, their relation to the till, and the explanation of their mode of origin, have been described in previous pages. Since the stratified deposits of the ground moraine are similar to those of the terminal moraine, further discussion of them may be omitted.

THE GROUND MORAINE WEST OF THE TERMINAL MORAINE.

The ground moraine west of the terminal moraine is in many ways different from that east of it. If the region were divided into two great divisions instead of three, the ground moraine west of the terminal moraine would be one of the divisions, and the eastern ground moraine would be joined with the terminal moraine to make another. In other words, there is a greater difference between the western and eastern ground moraines, than there is between the latter and the terminal moraine. These differences will be seen as the ground moraine on the west side of the area is described.

Distribution.

This division of the ground moraine occupies approximately 56 square miles, in a belt 2 miles wide at the north and 7 miles wide at the south. All the land in Dupage county west of the terminal moraine is included in it, except the small areas covered by outwash gravel along the edge of the terminal moraine, and a small area of esker gravels in the southeast part of sec. 3, Naperville township. (See Pl. II.)

Topography.

The first striking difference between the eastern and western areas of the ground moraine is in the topography. Most of the land west of the terminal moraine has a topography very similar to that of the flat type of the ground moraine, with irregularly arranged elevations and depressions of very slight relief. In some places the surface is almost flat, as in the stretch of country extending from the railroad-crossing between sec. 4, Winfield township and sec. 33, Wayne township, west to secs. 31 and 6. In this area there are no undulations of any considerable size, though close observation shows a slight waviness of surface. In the central part of secs. 31 and 6, small insignificant swells and depressions appear. The depressions are undrained and some of them hold standing water, at least after rains. The maximum relief is not over 2 to 3 feet. This is less than the average for this ground moraine as a whole, which is probably about 8 feet. West of Naperville the topography has a little more relief. This is due partly to streams which have cut below the original surface of the drift in some places. A good example of this type of surface is seen west of West Chicago as far as the county line, where the relief is about 10 feet in 2 miles. Very shallow undrained depressions are common and are distributed among low-rolling swells.

There are no such large areas of the flat topography in the eastern ground moraine, although there are some small areas north of Addison which approach it.

Constitution.

The material making up this ground moraine is similar to that of the ground moraine east of the terminal moraine. It is for the most part the typical yellowish or bluish clay containing numerous pebbles and small bowlders, and pockets and lenses of sand and gravel. The materials of the till and of the stratified parts of the drift are perhaps somewhat finer on this side of the terminal moraine than on its east side, and the surface bowlders are a bit scarcer, but the difference is not conspicuous.

The till can be seen at almost any place where the soil has been cut through. Exposures are rare, however, because the surface is so nearly flat that road and railroad cuts are unnecessary. But it is noticed that the roads are clayey rather than sandy, that they become muddy when wet, and that water stands on the surface for a considerable time after a rain. If sand or gravel underlay the surface, the water would disappear quickly. Nearly all the wells in the district penetrate clay, though most of them strike also pockets of sand and gravel.

Sand and gravel appear at the surface in several places; notably in the SE. 1/4 sec. 7, Winfield township, secs. 26 and 27, Naperville township, and the northwest part of sec. 10 of the same township. They are similar to those in the ground moraine to the east and need no further description.

Thickness.

The thickness of the drift over this part of the area varies from nearly zero to at least 125 feet. It is thinnest in the vicinity of Naperville, where the rock comes to the surface in several places. It is exposed on the south bank of the West Branch of Dupage river in the southwest part of Naperville at three old quarries in the limestone, and the same rock outcrops on the banks of the river for some distance along the stream. A mile south of Naperville in the NW. 1/4 sec. 30, Lisle township, a small patch of bed rock appears at the surface, where it was uncovered for quarrying purposes many years ago, though little rock was taken out. The thickest recorded drift in this ground moraine is at the canning factory at Eola, where a well (10) struck rock 125 feet from the surface. The average of six recorded thicknesses is 72 feet, which is about 50 feet less than the average thickness of the ground moraine east of the terminal moraine.

Manner of Deposition.

In general the western ground moraine was made in the same way as was the eastern ground moraine. It shows all the features of the latter, though they are less strongly marked. The topography is similar to that of the eastern ground moraine, in that its elevations and depressions are without definite arrangement. The materials making up the two ground moraines are the same in all respects. There is enough similarity between the two areas to lead us to conclude that they were made in about the same way. The drift of both areas consists of materials picked up by the ice as it moved from Canada through the basin of Lake Michigan, and deposited where the ice melted.

The difference in thickness and topography of the drift in the two areas is significant. The last ice sheet extended beyond this region to the west and south. While the whole region was covered by the ice it received a deposit of ground moraine like that now appearing in the western area. But when the rate of melting at the edge of the ice sheet came to exceed the rate of its forward movement, the edge receded to the east and north, and first uncovered the western part of the area. Then, owing to an increase in snow fall or to a decrease in temperature, the ice again moved fast enough to balance the melting at its edge, which therefore remained stationary along the line of the terminal moraine. This left the western part of the area uncovered while the terminal moraine was making beneath the edge of the ice sheet. Thus, after deposition had ceased in the west, it was still in progress over the eastern part of the area. This accounts for the presence of the terminal moraine, and partly, at least, for the thicker drift of the ground moraine to the east. (See fig. 8.)

From the rougher topography of the eastern ground moraine and its similarity to the terminal moraine, one other deduction can be made. When conditions had changed so that melting again exceeded ice movement and the ice edge receded eastward, it did so very slowly; more slowly than it had receded over the area west of the terminal moraine. This permitted the deposition of much drift to the east and served to give this part of the area a surface rougher than that of the western part. The edge of the ice receded so slowly indeed, that it gave the eastern ground moraine some of the characteristics of the terminal moraine.

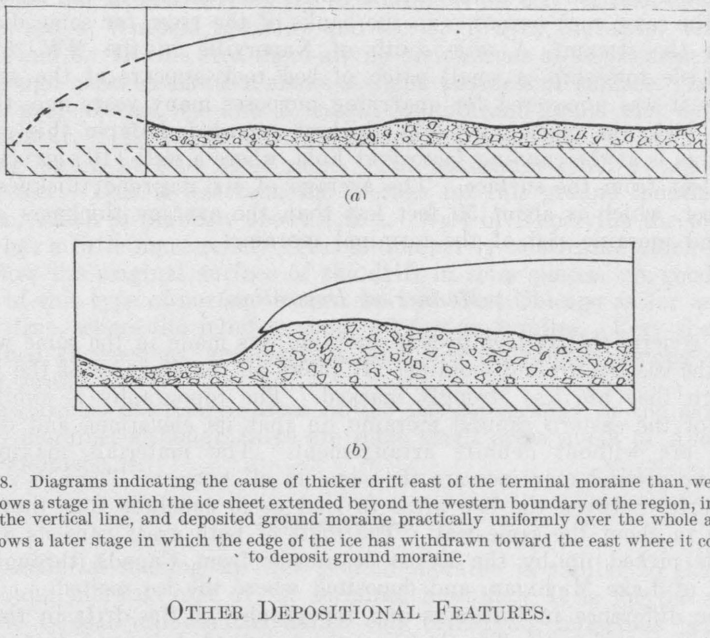


Figure 8. Diagrams indicating the cause of thicker drift east of the terminal moraine than west of it.
(*a*) Shows a stage in which the ice sheet extended beyond the western boundary of the region, indicated by the vertical line, and deposited ground moraine practically uniformly over the whole area.
(*b*) Shows a later stage in which the edge of the ice has withdrawn toward the east where it continues to deposit ground moraine.

Other Depositional Features.

While the ground moraine and the terminal moraine make up much the greater part of the drift of the Wheaton quadrangle, there are some minor phases deposited by the ice or its associated waters. None of these features have important extent, but some of them throw light upon the mode of formation of the larger phases of the drift, and others are interesting for the way in which they show special conditions at certain points in connection with the ice sheet. Outwash material, kames, and eskers are discussed in the order of their areal importance in the region.

OUTWASH MATERIAL.

Outwash material, as stated on page 21, is that material which is carried beyond the edge of the ice and deposited in certain positions by the waters derived from melting. Where a definite stream flows out from the ice through a valley, it deposits its materials in the valley and the result is a *valley train*. Where the water flows from many points along the edge of the ice, each small stream deposits its material near the edge, and if the ice remains stationary long enough the deposited material spreads out laterally until a plain of stratified material is formed lying along the edge of the ice and sloping gently from it. Such a feature is known as an *outwash plain*. After the ice has withdrawn from a region the outwash plain or valley train is left just outside of and adjoining the terminal moraine which was deposited under the edge of the ice at the same time.

There is considerable outwash material in the Wheaton area though it does not take the normal form of an outwash plain or of a valley train. It is found only in patches in connection with the terminal moraine and the eastern ground moraine. It is exposed at many places in gravel pits that are worked for road ballast. (See map Pl. II.)

The outwash materials occur most plentifully along the west edge of the terminal moraine. They do not form a continuous belt outside the moraine, but there is a narrow elongate area along its west edge where they occur much more frequently than in other parts of the region. More specifically, the outwash gravels appear in the eastern part of sec. 6, the western part of sec. 8, the southern part of sec. 17, and the southwest part of sec. 35, Winfield township, and in the eastern part of sec. 2 and the northwestern part of sec. 11, Naperville township. In the southern part of the valley of the West Branch of the Dupage river, south of the locality where the river passes through the terminal moraine, there are some patches of gravel along the sides of the stream which are not along the exact edge of the terminal moraine. Where the river swings close to the terminal moraine, it is hard to tell whether the gravels between them are to be connected in origin with the present stream or with the water which issued from the ice when the terminal moraine was making. Some patches certainly occur along the stream without direct connection with the terminal moraine, as those in the west central parts of secs. 22 and 27, Winfield township, and the northern part of sec. 14 and the western part of sec. 13, Naperville township.

An outwash plain is most nearly approached in a strip between the terminal moraine and the West Branch of Dupage river, in secs. 22, 27, and 35, Winfield township. The gravel here seems to be practically continuous along the terminal moraine, and it extends farther west than is its wont. Along the east side of the river for 2 miles is a low ridge of gravel. Everywhere in this strip of land where any record could be obtained, the underlying material is stratified. But the surface of the land is not flat, nor does it slope away from the terminal moraine as a typical outwash plain should. The surface is gently rolling and many of the swells suggest till rather than gravel. The terminal moraine to the east is more than ordinarily stout, seeming to show that the edge of the ice was stationary there for a relatively long time. This being the case, more outwash would be expected here than elsewhere along the terminal moraine. But there is another reason for a greater amount of outwash material here. At the north end of the strip the West Branch of Dupage river flows through the terminal moraine in a low place which has not been made since glacial times. A similar, though smaller, valley through the terminal moraine occurs 1½ miles farther south. The western ends of these valleys seem to have been points of outlet for subglacial streams. The larger of these streams probably flowed from the ice edge southward along the west edge of the strip where the West Branch of Dupage river now is, and was joined three-fourths mile north of Warrenville by the smaller one. These streams issuing from the ice were doubtless loaded with the debris which the ice had contained. They deposited their burdens in their beds and along their valley flats. When their channels were filled so as to cause the water to overflow, the rest of the material was deposited along the sides of the channels where the velocities of the streams were checked. Such a process gave rise to a low ridge along the larger stream. It seems that this material got far enough east to meet the materials which were being washed out directly from the ice edge toward the west, but there was apparently not enough gravel deposited quite to cover up all the irregularities of the underlying ground moraine, for the low swells seem to be till. The topography is thus a peculiar combination of that of a very poorly developed valley train, and of a still more poorly developed outwash plain.

Similar gravels occur in the lower valley of the East Branch of Dupage river, and to some extent in the upper part of the valley of West Branch east of the terminal moraine. In neither of these places is there great continuity to the stratified drift, nor anything that resembles a valley train. The stratified drift appears in low hills on the valley bottoms or on the east sides of the valleys, in connection with the higher land of the eastern ground moraine. The most noticeable of these deposits are in the west central portion of sec. 14, Wayne township, and in the southwest portion of sec. 1, Winfield township, in the valley of West Branch of Dupage river, and in the northeast part of sec. 27, the north part of sec. 15, the east part of secs. 10 and 3, Lisle township, in the valley of the East Branch.

One-half mile north of Lisle on the east side of the valley of the East Branch is a feature worth mention. It is a strip of land, resembling a terrace, one-fourth mile broad east and west and three-fourths mile long north and south, lying 15-20 feet above the valley bottom and considerably more than that amount below the eastern upland. The only cut in it is near its south end, where a small pit has been opened in the gravels (Pl. VI, *B*). But the surface of the terrace is neither flat like an outwash plain, nor hummocky like a kame-area.

Constitution.

Most of the outwash material would be classed as gravel rather than sand, though there is some sand in every exposure. It may be in definite layers or mixed in with the gravel.

There are distinct differences between this material and the stratified drift in the terminal and ground moraines. The latter is coarser and is but poorly stratified. The cobbles and bowlders in it range up to a foot or more in diameter, and those 6, 8, and 10 inches in diameter are common. The material too is but roughly assorted and the stratification lines are not continuous nor even.

In all these respects the outwash material is different. Further, the materials in the outwash are alike in different parts of a pit and also in different parts of the region. Gravels are separated from the sand in definite layers that are continuous for considerable distances in many cases. On the whole, the outwash consists of finer material than that in the drift or till. Pebbles larger than 3 inches in diameter are the exception in it rather than the rule. Occasional cobbles 4 or 5 inches in diameter are found, but not so abundantly as in the stratified drift. Moreover, the pebbles in the outwash show much more distinct effects of water wear than those in the drift.

A more definite idea of the outwash gravels will be obtained from a consideration of the details of a few type pits.

1. One of the best is in the SW. ¼, sec. 1, Winfield township, on the west side of the West Branch of Dupage river about 100 feet from the stream and 5 to 6 feet above it. The material here is exposed continuously in a 7-foot cut for a distance of 250 feet. It consists of fine gravel with pebbles averaging less than 3 inches in diameter, mixed with coarse sand. Only two bowlders larger than 3 inches in diameter were seen and these were 6 inches and 1 foot respectively. Stratification lines are distinct and as a whole regular, though some of the thinner layers pinch out rapidly in both directions. In many places, and not necessarily in any order or in any one layer, the gravels are stained red with iron oxide.

2. Another characteristic pit is on the west edge of the terminal moraine, on the land of C. H. Hoy, in the east central part of sec. 26, Winfield township. This pit is 15-20 feet deep in clean gravel and sand, the finer material being underneath. The upper 15 feet of the deposit is quite homogeneous. It consists of a clean mixture of coarse and fine gravel with occasional thin irregular layers of coarse sand. The pebbles of the coarse gravel frequently reach 5 inches in diameter. They are as a rule round. In the lower 5 feet sand predominates over gravel. The sand is coarse, and contains occasional layers of fine gravel. The stratification lines are irregular, and the layers wedge out in all directions. The sand layers show cross-bedding within themselves.

3. In the southern part of sec. 18, one-half mile east of Naperville on Chicago Ave. road, are two gravel pits owned by Mr. Clemens. In the south pit the material is exposed to a depth of 18 feet. It consists of gravel and coarse sand, but no clay. Layers of mixed gravel and sand bear all relations to layers of clean gravel and layers of coarse sand. The north pit affords the best exposure of outwash material seen in the region. A 35-foot cut shows well-defined, regular layers of sand and fine gravel. Most of the layers are continuous and of constant thickness. Stratification lines are parallel. Some of the lower sand layers show cross-bedding. (Pl. VII, *A*.)

Manner of deposition.

From the distribution and constitution of the outwash gravel it is clear that it was deposited by water. Its relatively fine material, its cross-bedded sands, and rounded pebbles point to running water as its transporting and depositing agent. Its distribution in the valleys and along the outer edge of the terminal moraine bears out this conclusion, as the water flowing from the edge of the ice would take the lowest places in the surface.

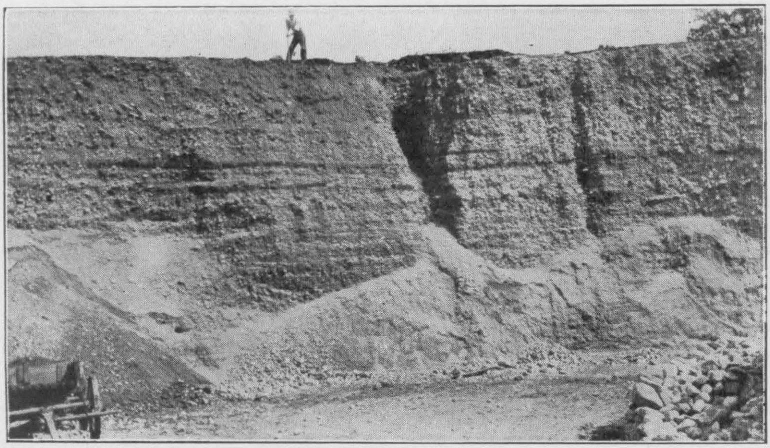
Thickness.

No very satisfactory estimate of the thickness of the outwash materials has been made. Aside from measuring the exposures in the pits the only way of ascertaining it is by well records. Because of the infrequent occurrence of gravels, and the fact that they are water-bearing, and consequently wells do not pass through them to obtain water, few records of value are available. Just west of the terminal moraine on the south line of sec. 33, Wayne township, a well (3) is reported to have been dug 62 feet in gravel. In the southeast part of sec. 22, Lisle township (59), in the bottom of the valley of the East Branch of Dupage river, a depth of 72 feet of gravel is recorded. Inasmuch as both of these wells were dug in situations favorable for the deposition of these gravels, and since outwash gravels occur at the surface near them, it is likely that the gravels recorded are those of the outwash.

The outwash and the recession of the ice edge.

On page 44, reference was made to the movements of the edge of the ice, as shown by the difference between the ground moraine east and west of the terminal moraine and the likeness of the eastern ground moraine to the terminal moraine. It was pointed out that the edge of the ice had receded over the eastern ground moraine more slowly than over the western, but more quickly than over the site of the terminal moraine where the ice was probably stationary for some time. The same facts are indicated by the relative amounts of outwash materials in the different parts of the region.

Where the topography of the terminal moraine is roughest, there is the most outwash material in connection with it. The roughest part



A. Outwash gravels one-half mile east of Naperville.

B. Profile of kame north of Naperville.

of the terminal moraine is to the east and north of Wayne, and along its outer edge at this place is the most outwash gravel. Again the terminal moraine is more than usually strong between Warrenville and West Chicago, and at this place also there is a relatively large amount of outwash material in connection with it. The roughest part of the eastern ground moraine is in the southwest part of the area, east of the valley of the East Branch of Dupage river, and the lower part of this valley contains more outwash gravel than its upper part where the land to the east is not so rough.

Since the outwash is connected with the edge of the ice, it would be expected that where the edge remained the longest, the most outwash material would be found immediately beyond it—conditions of ice load being the same. But as rough topography and outwash material go together, it follows that the rough topography is due also to a slow recession of the ice edge. This strengthens the idea that the edge of the ice receded more rapidly over the western ground moraine than over the eastern, and more rapidly over the latter than over the terminal moraine.

Another point of interest brought out by the relations of the outwash to the ground moraine refers to the origin of the valleys of the East and West Branches of Dupage river. These valleys are probably due to irregular depositon of the drift. Their bottoms are not very rough and the drift under them is probably relatively thin. If we are right in concluding that relatively rough and thick drift means a relatively slowly receding ice edge, we may explain these two valleys as follows. The ice edge remained stationary over the present terminal moraine and deposited a thick rough body of drift under itself. It then receded with relative rapidity to the east until the edge stood east of the valley of the West Branch, where its recession was somewhat retarded. Thus there would be produced two ridges with a trough-like depression between them. In the same way the valley of the East Branch may represent the position of a relatively rapid recession of the edge, which left a depression between two thicker bodies of drift. When the edge of the ice stood east of the valley of the West Branch, the waters resulting from the melting ice ran from its edge and, encountering the ridge of the terminal moraine, stood in the depression or ran off along the inside of the ridge by the lowest route; that is along the line now followed by the West Branch. Similar, when the edge stood east of the valley of the East Branch its waters discharged into the valley and flowed behind the higher drift body to the west, that is, along the line now followed by the East Branch of Dupage river. In this way would not only the stratified drift in these two valleys be accounted for, but also the valleys themselves.

It is conceivable that valleys may have existed along these lines before the advance of the ice and that the positions of the present valleys were determined by the positions of earlier ones, since the drift deposited in the valley troughs would lie lower than that deposited on the sides. But there is no evidence from well records or elsewhere that the rock surface is lower under the present valleys than beyond them, nor can it be proven that it is not lower, since water is obtained in the valleys by very shallow wells and consequently none has been drilled to rock. The conditions are shown by the following records:

Records of wells on west side of valley of East Branch Dupage river.

Well number.	Elevation of well site.	Depth to rock.	Altitude of rock above sea level.
	Feet.	*Feet.*	*Feet.*
35	800	158	642
36	813	140	673
38	750	100	650
51	760	144	616
45	740	112	628
52	770	172	598
56	755	108	647
57	730	97+	
Average		129+	643.5

Record of wells on east side of valley of East Branch of Dupage river.

Well number.	Elevation of well site.	Depth to rock.	Altitude of rock above sea level.
	Feet.	*Feet.*	*Feet.*
70	730	112	618
68	770	115	655
65	720	90	630
Average		106	634

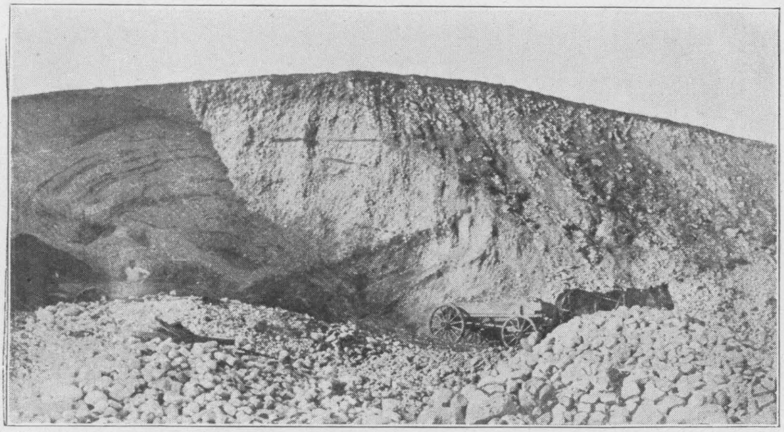
Records of wells in or on the edge of the valley.

Well number.	Elevation of well site.	Depth to rock.	Altitude of rock above sea level.
	Feet.	*Feet.*	*Feet.*
67	692	$9\frac{1}{2}$+	$682\frac{1}{2}$
66	680	60 +	620
62	700	44 +	656
59	670	72 +	698
Average		46 +	615

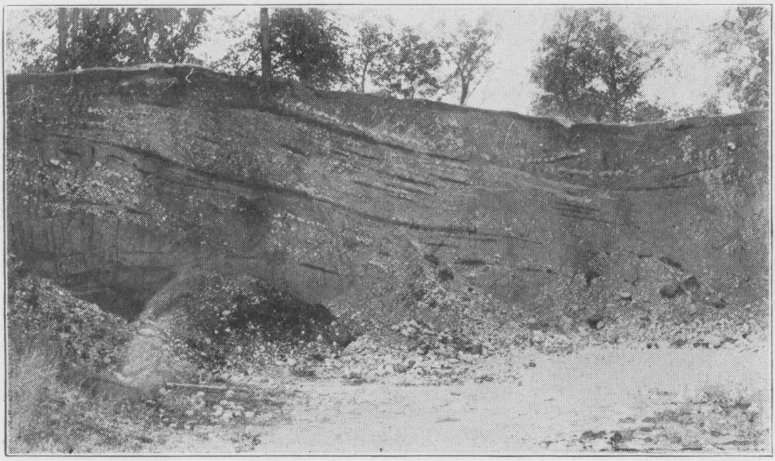
If the present valleys occupy old valleys, the occurrence of outwash materials in them would be explained exactly as under the first hypotheses. The valleys would be the places for the concentration of the waters and, consequently, also for the deposition of the gravels.

KAMES AND KAME-AREAS.

Kames are hillocks or short ridges of stratified drift formed chiefly at the edge of the ice. The edge of an ice sheet is commonly irregular



A. Cut in kame giving general view of its material.



B. Side of pit in kame in section 24, Milton township, illustrating arrangement and character of materials of which it is formed.

with projections and reentrants. Where a stream emerges from the ice into a reentrant, some of its gravel and sand is deposited. Although a stream may flow swiftly while under or within the glacier, its velocity is checked where is emerges from beneath the ice. Where this takes place, there is an immediate decrease in its power of carrying sediment, and rapid deposition takes place. When the edge of the ice melts back, the gravel and sand previously dumped within the reentrant and piled against the ice walls, settle and take the form of more or less irregular hillocks and short ridges (fig. 9).

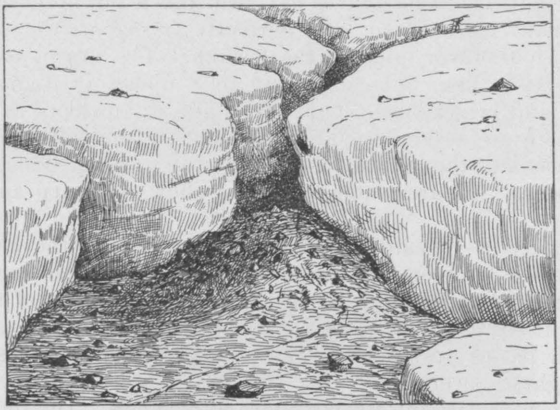


Figure 9. Diagrammatic sketch illustrating the method of formation of kames.

Since they are formed at the edge of the ice, kames are found most often in terminal moraines, though they are not confined to this position. If surrounded by ground moraine, they were formed at the edge of the ice presumably while it was receding. Kames are not rare in the glaciated area of North America. They may occur singly or in groups, and in the latter case well-defined, hummocky kames grade off through undulating tracts of stratified drift to plains. Ill-defined groups of kames are sometimes called kame-areas.

Distribution and description.

There are several kames in the Wheaton quadrangle and at least two areas where kame-like deposits occur. The kames vary considerably in size, height, and materials.

In the west central part of sec. 6, Lisle township, on a farm rented by Frank Schuster on the west side of the north-south road, are two small adjoining kames. They appear as two rounded, gently sloping mounds, situated in a rather flat tract at the south end of the terminal moraine. Both are slightly elongate in an east-west direction. The one to the west has a width of about 100 feet, a length of 200, and a height of 20. It is scarcely separated from the eastern kame, which is about

150 by 200 feet at the base, and about 25 feet high. The north side of each kame is slightly steeper than the south side. Plates VII, *B*, and VIII, *A*, give an idea of the topography and material of these kames.

A 25-foot cut in a gravel pit on the east side of the east kame exposes the material of which it is formed. This is coarse and fine gravel, sand, and a little clay. In the middle of the kame, the cut shows gravel and sand from the highest point of the kame to the bottom of the pit. Stratification lines are somewhat irregular and not everywhere continuous, the materials being in pockets rather than in layers. The material is so loose that it does not long maintain a vertical face, and in the north side of the pit where no gravel has been taken out recently, it lies at a slope of about 20°. Even in a perfectly fresh cut, the material keeps falling down to form talus at the bottom. The gravel is for the most part moderately fine, but cobbles up to 8 inches in diameter are common in it, and larger ones occur. In a pile of bowlders in the center of the pit, there are several as large as 3 feet in diameter. Most of them are of limestone, though there are some of granite, diabase, and other igneous rocks. All are water-worn and show no sharp angles or striations.

The Naperville-Wheaton road 1½ miles east of the kames just described, passes between two other considerably larger kames, forming rather sharp and conspicuous knobs. The more westerly of the two stands 40-60 feet above the land to the south, and 80-100 feet above the east-west road which passes just north of it. The kame on the east side of the road is slightly lower.

The material is essentially alike in both kames. On the west side of the west kame is a large pit not now in use. The material is almost entirely gravel, ranging up to small bowlders a foot in diameter. Probably over 90 per cent of the stony matter is limestone, with some granite and diabase. The structure cannot be seen on account of the talus.

Another kame occurs in the north central part of sec. 24, Milton township, on the property of Mr. Baker. It stands conspicuously, not only above the flat topography of the valley of the East Branch, but it is also higher than the upper plain back of it to the west. A cut on the north side shows its material to be of gravel and sand. Cross-bedding is evident in the sandy layers. (See Pl. VIII, *B*.)

Of these kames, those on the Naperville-Wheaton road are the largest and contain the coarsest material. The inference is that they were deposited by the largest and swiftest of the kame-making streams.

In two larger areas, one east of Glen Ellyn and the other in and around Bloomingdale, the topography is controlled by kame-like drift, though no well-defined kames occur. These areas are called kame-areas rather than kames. These areas are shown on the accompanying map. (Pl. II.)

The kame-area east of Glen Ellyn is about one square mile in extent. It includes the eastern part of the village and extends east to the East Branch of Dupage river. The beauties of the Glen Ellyn park and of the Camp Ground near the Taylor Avenue station of the Aurora, Elgin, and Chicago Electric R. R. are due to these kame deposits.

A. Photograph illustrating undulating topography in the Glen Ellyn kame-area.

B. Section of the deposits in the Glen Ellyn kame-area.

The topography in this area is very similar to that of the more knobby parts of the terminal moraine. It is best seen around the camp grounds in the west central part of the area, and on the south side of the little lake on the east edge of the village. Small kettle-like depressions and sharp stratified knolls abound. The topography is sharply undulatory, with frequent abrupt slopes. A similar topography is seen all along the steam and electric railroad to the East Branch of Dupage river. (See Pl. IX, *A*.)

There are many gravel pits and railroad cuts in this area, and all show stratified drift. Gravel appears at the surface along the north-south road just east of Glen lake and in wells and basements of houses in the southeastern part of Glen Ellyn. For details of this material see Plate IX, *B*. There is however, some till in the area, underlying the stratified materials.

The kame area at Bloomingdale is very similar to that east of Glen Ellyn, though smaller. The topography in and immediately surrounding Bloomingdale resembles terminal moraine topography. The elevations are knobs rather than swells, and are more conspicuous than the depressions. Where the elevations of the typical ground moraine have an average diameter at the base of about 200 yards, the elevations near Bloomingdale have a base diameter of not more than 100 feet. They have relatively steep slopes and join one another in such a way as to give the surface a sharply undulatory appearance, without presenting any one elevation which might be called a kame. The topography is determined not by a group of separate kames, but by a large number of adjoining kame-like elevations, each spoiling the characteristic shape of its neighbors.

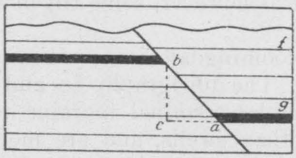
A very large part of the material of this area is stratified. In about two quarter sections covered by the rough topography, 9 gravel-and sand-pits were noted. Besides these, gravel appears at many places at the surface where pits have not been opened. Outside of this area little gravel is seen at the surface within 5 miles in any direction. The materials exposed in the pits vary in size from fine clays and silts to bowlders a foot or more in diameter. At one pit the deposit contains so much sand and very fine gravel that it requires only rough sifting for use in the manufacture of cement blocks.

Faults in the Glen Ellyn kame-area.

A rather uncommon feature for loose material was observed in one of the kames one-half mile east of Glen Ellyn. Twenty-five feet from the east end of a 150-foot cut for a road and sidewalk, the layers of fine gravel, sand, and clay were seen to have been broken and displaced relatively on the two sides of the break.

Any displacement of beds in connection with a break crossing them is known technically as a *fault*. In any faulted rock the amount of displacement measured vertically is the *throw*, and that measured along the fault plane is the *displacement*. The angle between the fault plane and the horizontal is the *dip,* and between the fault plane and the vertical is the *hade.* The side that has moved relatively upward is the *upthrow side,* and that which has moved downward is the *downthrow side.*

Faults may be due either to lateral compression, causing folding of the rocks until they break, or to tension, such as that which results from shrinkage, allowing the parts of the beds to slip down from their original position on one side of the crack farther than the parts on its other side. In faults due to compression, known as *thrust* or *reversed faults,* the fault plane dips toward the upthrow side (fig. 11). In faults due to tension, known as *gravity* or *normal faults,* the fault plane dips toward the downthrow side (fig. 10).



igure 10. Diagrammatic cross section through a normal fault. *bc* = the throw, *ab* = the displacement, angle *bac* = the dip, angle *abc* = the hade, *abc* = upthrow side with *ab* = the foot wall, *afg* = downthrow side with *ab* the hanging wall.

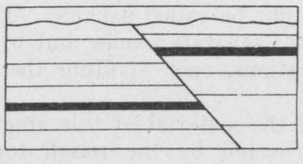


Figure 11. Diagrammatic cross section through a reversed fault.

The most conspicuous fault in the kame area of Glen Ellyn is sketched in figure 12. The kame in which it occurs gives place on the east to a kettle 40 feet below the top of the kame. The fault plane dips toward the southeast and toward the kettle at an angle of 57°. Since the southeast side of the faulted area was downthrown the fault is a normal one. The displacement is 10 inches and the throw slightly less. Referring to the photograph, it is seen that the most distinct bed does not match on opposite sides of the break (Pl. X).

Higher up, the beds are so indistinct that it cannot be seen whether they match or not. Here the fault shows itself in a different manner. In the parts of the beds not disturbed by the fault, the pebbles of the gravel lie with their flatter sides parallel with the beds, that is with their flat sides essentially horizontal. For 2 or 3 inches within the zone of the fault, however, the pebbles are turned to lie with their flat sides

Fault in kame material one-half mile east of Glen Ellyn.

parallel with the fault plane. This difference in the relative position of the pebbles in the beds and the fault cracks, by contrast, makes the distinct line shown in the photograph. The turning was accomplished by

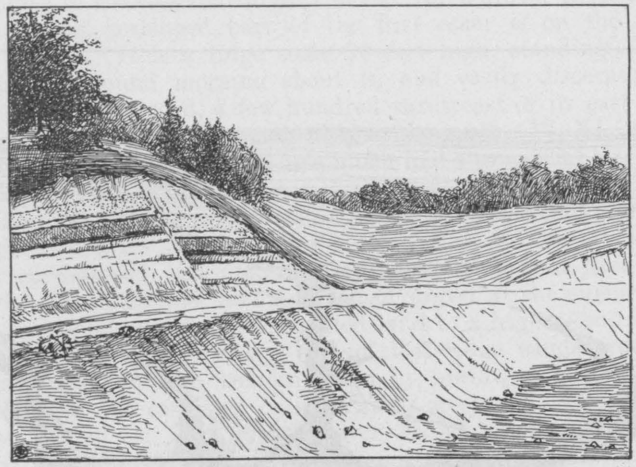


Figure 12. Sketch of fault in kame east of Glen Ellyn.

the rubbing of the ends of the faulted beds upon one another, in the same way that a silver coin held horizontally between the hands will come to lie parallel with the hands if one hand is lowered.

The cause of the faulting at this place is simple but interesting. The kettle east of the kame is one of the symmetrical ones which was formed by the melting out of a buried ice block. Presumably before the melting of this block the surface of the kame and the surface of the material over the block were more nearly on a level than now. When the ice block melted and the material over it sank the kame material tended to follow in consequence of the pull of gravity. Thus, the east side of the kame settled 10 inches toward the kettle.

Development of kame-areas.

The kame-areas were probably formed where the edge of the ice was much fissured by cracks running into and crossing one another. Either the melting ice, or the sub-glacial streams issuing from under the ice, furnished the water which circulated through these cracks and deposited its load. When all the ice had melted away, this material was let down and took the form which we now see in kame areas. (See figs. 13 and 14.)

Kame-areas might be produced also by local oscillation of a ragged edge of ice, depositing kames on and about other kames, as the ice edge advanced or retreated slightly.

ESKERS.

Eskers are ridges of stratified drift. They are not so common as kames, though many are known in the glaciated portion of North America.

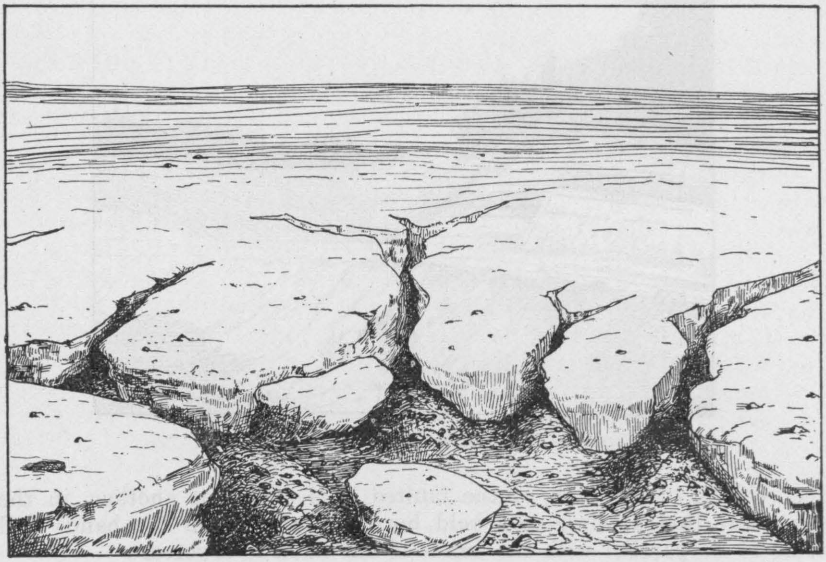


Figure 13. Diagrammatic sketch to show how kame-areas are formed in connection with a much fissured ice edge.

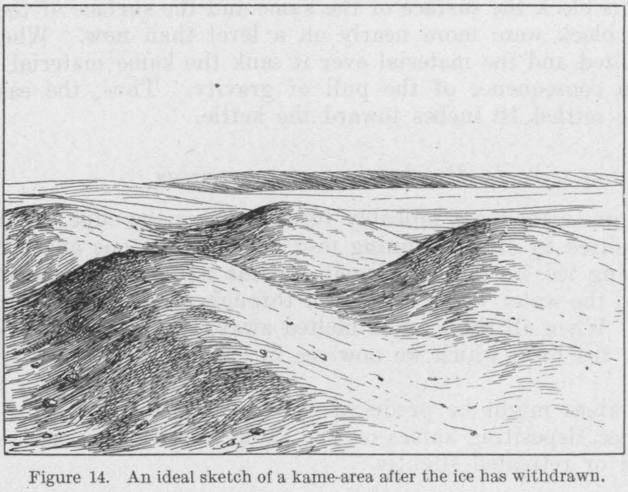


Figure 14. An ideal sketch of a kame-area after the ice has withdrawn.

Location and description.

Two eskers occur in the Wheaton quadrangle, one in the south central part of sec. 3, Naperville township, 2½ miles northwest of Naperville and the other in the east central part of sec. 15, Winfield township. The largest and best developed part of the first esker is on the farm of Edward Kearns. It is a ridge some 20 feet high, standing above the gently rolling ground moraine about it, and easily discernible from both the north-south road, a few hundred yards east of its east end and from the east-west road one-fourth mile to the south (Pl. XI, *A*). The ridge is not straight, but has a course much like a somewhat straightened letter S. (See map, Pl. II.)

From a gravel pit 200 yards west of the north-south road, a low, somewhat indefinite ridge can be followed westward for 500 or 600 feet, where it spreads out and almost disappears. But from this point a very slight rise of ground, and a streak of gravel at the surface can be followed for 100 feet through cultivated land to a higher, better-defined ridge to the west. The western part of this ridge winds around in a broad curve for 850 feet, trending west by southwest at its east end, and attaining a due east-west position at its west end. In this part of its course it is 20 feet high, and not over 50 feet across at the base. It reaches its greatest height at its west end, spreads out, breaks for 25 feet, then collects again in a final knob, not quite so high but elongate in the general direction of the ridge. The total length of this part of the esker including all its turns is about 1,600 feet. The esker ends here, so far as typical physiographic features are concerned but there are suggestions of its continuation to the west. About 600 feet southwest of the definite ridge there is a single kame-like knoll 20 feet high and 150 feet through at the base, standing conspicuously on the plain. Eight hundred feet west of the kame there is an old gravel pit cut in a low narrow ridge which extends for 500 feet east and west. One hundred feet beyond the west end of the pit there is another one, 700 feet long in a general northeast-southwest direction. Where almost destroyed by the pits, the ridge shows only in a slope up to the rims of the pits, on either side and by elongate shape of the pits. Including this indefinite part of the feature, all its curves, and all its discontinuities, the esker has a total length of about three-fourths mile. (See map Pl. II.)

The esker is composed entirely of gravel and sand. A small pit opened at its extreme east end exposes alternating layers of coarse sand and fine gravel. In the now unused part of the pit the material was evidently coarser than in the part now used, as shown by the bowlders in the talus. On the rock pile, many bowlders are 1 foot in diameter, several are 1½ feet, and at least two others measure 2 feet. In the fresh part of the pit, the gravels and sands are well arranged in layers which dip to the south on the south side of the cut. Gravel also appears on the top and sides of the ridge throughout its length, just as it appears on the top and sides at the gravel pit. Similar material is exposed in the older pits west of the more definite part of the ridge. It will be noticed from the map that gravels occur also in a narrow belt crossing the road east of the ridge. This material, while not taking the form of a ridge, was probably deposited at the same time and under similar conditions as that in the esker.

The esker in the east central part of sec. 15, Winfield township, is on land rented by Mr. Wallace. It is located in the bottom of a valley cutting through the terminal moraine. This valley is now occupied by the West Branch of Dupage river, which flows along the west side of the esker.

This esker is a definite ridge, parallel with the valley in which it lies, and with the present course of the West Branch. Its width on top is 20 to 30 feet. On its west side it descends abruptly to the river, a vertical distance of 30 feet. On its east side it slopes more gently to the low rolling plain in the bottom of the broad valley. In its most clearly defined part, its basal width is 100 feet, its height 20 to 30 feet, and its width at the top about 10 feet. This ridge has not the winding course of the esker northwest of Naperville.

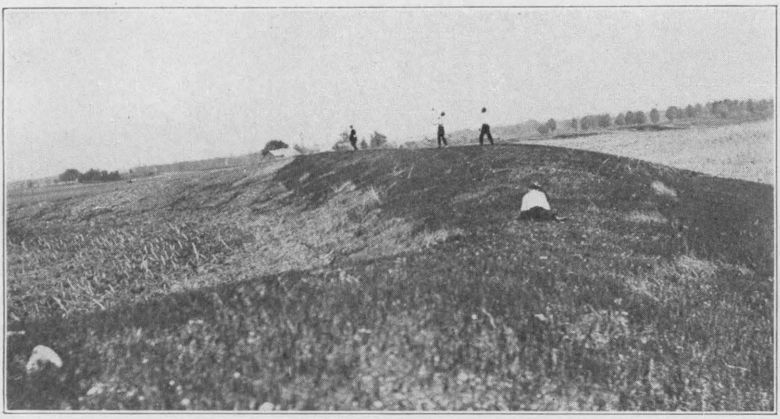
The material making up this ridge is similar to that of the esker northwest of Naperville. Gravel appears all over its surface and is exposed near its north end in a shallow pit.

Formation of eskers.

The most generally accepted theory for the formation of eskers explains them as being deposited by streams under the ice. Streams have often been observed to emerge from beneath the edge of modern ice sheets and other glaciers. Consequently they must extend back under the body of the ice. Where such streams emerge from the ice they are usually overloaded with debris which they deposit either in the form of kames at the edge of the ice, or as valley trains or outwash plains beyond the edge.

When a well-loaded subglacial stream follows a definite channel and is confined by the ice above it, any material which it deposits can be dropped only on the bed of the stream. If this deposition goes on long enough, the bed will be built up, until the stream, being confined by the ice above, will come to flow upon the ridge of material which it has deposited. This theory of the formation of an esker is greatly strengthened by the fact that eskers, more often than not, have winding courses like a stream, and that they commonly end in kames or valley trains.

There is nothing observed in connection with the eskers of this region to cast any doubt upon this theory. On the other hand, all of the features of the two eskers point toward such a mode of deposition. Most of the materials of both eskers are just such as are carried and deposited by running water. The larger bowlders might have been melted out of the ice above the stream, and have dropped down to become mixed with the finer sediment carried and deposited by the stream. The esker northwest of Naperville has a winding course and terminates at the west end in a kame. The one in Winfield township occurs in a depression through the terminal moraine, and lies upstream from other gravel deposits like valley trains. It is possible that the depression through the terminal moraine is due to a subglacial stream, which kept it cleared out while



A. Esker northwest of Naperville.

B. The contact between glacial drift and the rock (Niagara limestone) at the Naperville quarry.

more material was being deposited from the ice on either side of it. If so, the main work of the stream was that of erosion, though it must have deposited locally for a time at least, in order to have made the esker.

As noted above, the esker northwest of Naperville is not continuous throughout its course. This result would follow if the stream by which it was deposited was sharply confined by the ice in some parts of its course, but was allowed to spread in others. Where the ridge is definite the stream was so confined that deposition could take place only in the narrow channel. In the places where it is broken or indefinite, the stream was probably spread out more or less. The stratified drift immediately east and to the west of the esker, but not definitely a part of it, was probably deposited by the same stream that made the esker and at the same time, the difference in the two deposits being due to the fact that in one case the stream was not sharply confined, and thus spread out its materials in these places, while in the other case, it was confined and the ridge was formed.

EFFECTS OF GLACIAL EROSION.

It is clear that an ice sheet which deposited such a great amount of debris, must have eroded powerfully the rock over which it moved in order to get the drift which it deposited. The existence of the drift is good evidence of the erosion by the ice sheet. The fact that so large a part of the drift has not been carried far, shows that much erosion took place in or near this region.

Other specific evidence of glacial erosion in this region is scarce. The surface of the bed rock is exposed only in the quarries in the vicinity of Naperville, and it is only here that the erosional effects of the ice on the bed rock can be seen. From the meager data available, it seems that the surface of the rock was not everywhere greatly affected by glacial erosion before the drift was deposited. At the Naperville quarries the drift lies immediately upon the rock with no soil between them, showing that enough erosion took place before the deposition of the drift to remove any soil which once lay on the bed rock. But the surface of the bed rock is not striated, nor does it show any of the characteristics of a strongly eroded surface (Pl. XI, *B*). In three places where the drift was removed, the rock surface was found to be affected by minor irregularities due to weathering; but as the rock was uncovered only where the drift was thin, it is possible that this weathering has taken place since glacial times. At the outcrop 1 mile south of Naperville the plane between drift and bed rock is obscured by loose angular fragments of the limestone, which grade into the typical drift above. But the drift here is only two feet thick, and weathering may well have affected the rock through it. Neither here nor at Naperville is there any evidence of strong erosion. Deposition seems to have been the main work of the ice in those parts of the region where the surface of the bed rock is to be seen. It does not follow however, that this was the case everywhere.

SUMMARY OF FEATURES DUE TO GLACIATION.

The glaciation of the Wheaton area produced a surface much like that of today. The new surface is the top of a thick body of drift, about 100 feet above the surface of the bed rock. The relations of the new surface to the old one are summed up in the generalized section below (fig. 15).

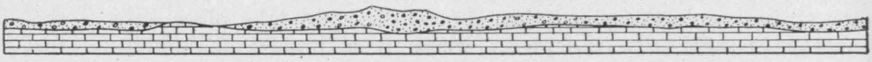


Figure 15. A generalized diagrammatic section across the Wheaton quadrangle from east to west, showing the glacial drift overlying the rock beneath. It will be seen that the configuration of the present surface has no definite relation to the configuration of the surface of the rock. Length of section 14 miles. Vertical scale exaggerated about 6 times.

As the topography of the lower surface must be learned from well records alone, it is somewhat conjectural, and may lack accuracy of detail. It appears that the drift surface does not differ profoundly from the rock surface, although it has more relief, is slightly rougher, and is about 100 feet higher. It is probable however, that the old surface was distinctly different from the present one in the arrangement of its elevations and depressions. The present surface is due to the deposits left by the ice sheet, and the elevations and depressions have no regular arrangement, while the old surface, being shaped largely by stream erosion, doubtless had its elevations and depressions arranged with respect to the streams that made them.

CHAPTER IV—POST-GLACIAL CHANGES.

IMMEDIATE CHANGES IN DRAINAGE.

As has been shown above, the valleys of the east and west branches of the Dupage river are probably due to unequal deposition of drift. When the ice first withdrew, these two elongate depressions were left in the surface between drift ridges. First the waters from the melting ice, and later the water from rain and melting snow, accumulated in these depressions. If water came into them faster than it could seep through the gravels and clays below, bodies of standing water resulted. The water gradually rose, spreading over the lowest ground, until it found outlet in the lowest places in the boundaries of the depressions. If these lowest places were high enough above the bottoms of the valleys to make dams, lakes were formed and must have remained until the barriers were cut away by the erosive action of the overflowing water.

But there are no evidences of the former presence of lakes in either of these valleys. There are no lake deposits, or any evidences of old shore lines. Neither is there any sign of restraining dams which have been cut away. So far as can be seen, the waters in both valleys found immediate outlets. A slope to the south already existed when the ice withdrew, and the waters which flowed into the valleys ran out again immediately. The waters which accumulated east of the terminal moraine found an outlet through the gap in the terminal moraine southwest of Winfield, where the West Branch now crosses the terminal morainic ridge. From there the waters followed the lowest route to the south along the course of the present stream. The water in the valley between the two ridges farther east also drained off to the south, until it joined that from the West Branch and flowed on with it to the Des Plaines river.

A stream becomes permanent when the bottom of its valley is below the level of ground water. Evidently the bottoms of these valleys were below this level of saturated drift when the ice first withdrew, for their bottoms have not been appreciably lowered since then, and they contain permanent streams.

The main drainage system of this region was therefore established immediately after the withdrawal of the ice sheet. What the drainage system was before the ice advanced over the region, is not known.

SUBSEQUENT CHANGES.

As soon as the land surface was exposed after the melting of the ice, certain processes became operative which tended to wear it down, or degrade it. Such degradational processes are included under the terms *weathering* and *erosion*.

Processes of Weathering.

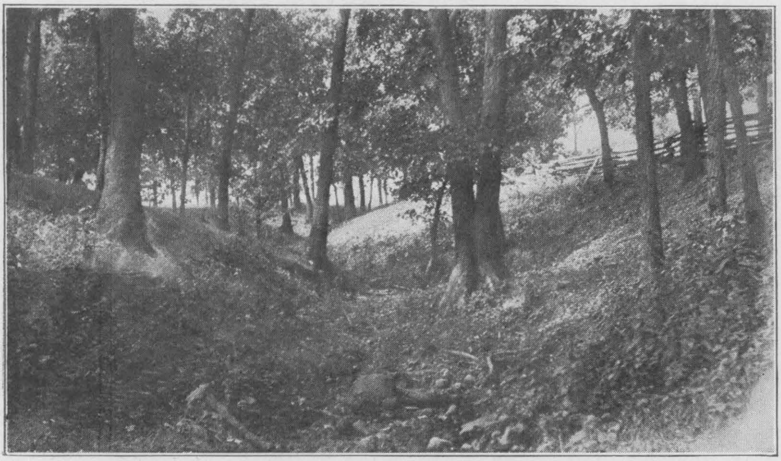
Under weathering are included all those unobtrusive processes which tend to break up, disrupt, or alter the materials of the surface of the land.

Changes of temperature work in two ways upon a land surface. As rock is warmed it expands, and as it cools it contracts. The changes of volume set up strains and stresses within the rock, which tend to break it. Where rocks are in small pieces, as in the drift, these changes in temperature produce but slight results. They produce the greatest results at high altitudes where there is a great daily range of temperature, though effective to a more or less extent on every land surface. If the changes in temperature oscillate above and below the freezing point of water, rock disruption is accomplished in a slightly different way. Where cracks or pores occur in the rock surface, as they do everywhere, they often contain water. If this water freezes, it expands with an expansional force sufficient to cause it to act as a wedge in widening the cracks. The results of changes in temperature can be seen in almost any high spot where the bare rock is exposed to the air. Plate XII, *A*, shows a talus slope in Wisconsin where hard quartzite has been disrupted chiefly by changes of temperature.

The processes of weathering have been active in this region in breaking up the bowlders of the drift, although sufficient time has not elapsed since the glacial period for any great amount of such work to have been done. Most of the surface bowlders are still apparently as fresh as when they were deposited by the ice, but occasionally one is seen, from which small pieces have dropped or can be very easily broken by a slight tap of the hammer. Occasionally bowlders are found which are so much decayed that they can be picked to pieces with the fingers, but this is due to chemical rather than to mechanical processes.

Moving air or wind is also an effective agent in modifying the shape of the surface. Winds are often strong enough to pick up the finer parts of the surface material, such as clay particles and sand grains, and move them from place to place. In the course of their transit they are not only worn smaller themselves, but they wear the surface against which they strike. The wear of the surface naturally proceeds most rapidly where its material is soft and the winds are high, as for instance in a region which is underlain with clay or friable sandstone, and where the winds are strong and are able to get fragments harder than the rock to be worn. Ideal conditions would exist for the wearing away of soft clay by wind-blown sand where there was sandstone outcropping near by, from which the wind could pick up sand.

A. Talus slope of quartzite in Wisconsin, illustrating effect of changes of temperature in disrupting rock.



B. Young valley in drift. Lisle township.

Immediately after the ice withdrew, before the surface of the drift was covered with vegetation, the winds had a good chance to move about the finer materials on the surface. While it could not move the pebbles or bowlders of the drift, the sands and clays were loose and light, and the winds doubtless moved them from place, sorting them out from the coarse parts of the drift in some places and dropping them on top of the drift in others. However, this did not take place to an extent great enough to have any appreciable effect on the surface of the region today. No dunes or piles of dust were left, and no distinct bowlder beds laid bare by the wind can be found.

Plants and animals also affect the land surface. Animals burrow into the ground and bring up material to the surface where it can be acted on by wind and running water. Plants send their roots into the ground and loosen the drift. They also die, adding organic matter to the rock material, which, when it decays, produces acids which corrode the rock and cause it to disintegrate. Plants and animals have helped materially in this region in forming the soil which covers the unaltered drift.

Ground water also plays an important part in weathering. That part of the water which falls on the surface and sinks in is known as "ground water." It always contains a small quantity of carbon dioxide which it absorbs from the atmosphere. As this water percolates through the pores and cracks of the drift, it changes the material physically or chemically. It dissolves calcium carbonate from the limestone particles causing them to disintegrate. If calcium in the rock is united with some other substance than carbonic acid, this compound may be broken up by the carbonic acid gas with the water, and calcium carbonate be formed. This is known as *carbonation.* The calcium carbonate thus formed dissolves in the carbonated water, and as in the case of limestone, disintegration of the rock results.

That the ground water has done some work on the drift of this area is evidenced by the coating of calcium carbonate on some of the stones of the drift and by the presence of nodules of lime within it. The waters have dissolved the substance from some parts of the drift and deposited it elsewhere. However, relatively little has been done by the ground water in the disruption of the drift.

Water itself may enter into combination with other substances in the drift, thus changing their composition. This is known as *hydration.* Ground waters also carry oxygen below the surface. This it adds to the compounds already existing, thus increasing their volume and weakening the rock of which they form a part. *Oxidation* also takes place at the surface without the aid of water, the oxygen of the air joining directly with the components of the drift. The result of oxidation is illustrated where the drift appears red or yellow. The iron compounds of the drift have been oxidized and hydrated and iron hydroxides have been formed; in a popular sense the drift may be said to have rusted.

THE EFFECT OF WEATHERING ON THE SURFACE OF THE DRIFT.

Soil formation.—Everywhere in this region the drift is covered with a fine-grained, black soil which is distinctly unlike the drift itself. For the most part, this soil contains few pebbles and bowlders, is relatively free from sand, and yet cannot be said to be clay. It is rather a carbonaceous loam, loose and more finely divided than any part of the drift below it. The drift grades into the soil above it by imperceptible stages, there being no sharp line between them as there is between the drift and the bed rock.

Though physically unlike the drift, the soil has been made from the drift by the various processes of weathering. Plant roots have wedged in between the drift particles and have left organic remains there. Worms and other animals have brought up finer material from beneath its surface. Percolating waters have penetrated it, dissolving out calcium carbonate and other substances. Temperature changes in the atmosphere have caused tiny bits to scale off the stony matter of the drift and winds have shifted its smaller particles, wearing them and everything they touched, smaller. The oxygen, carbon dioxide, and water of the air and of the ground water have acted chemically upon some of its components. Rain drops have beat upon its surface and helped in the work of disintegration. In all of these ways and probably in many others, the surface of the drift has been made into soil during the great number of years that have elapsed since the glacial period.

Processes of Stream Erosion.

Of the water which falls on the surface of the lands, some is evaporated from the surface, some sinks into the ground, and the rest runs off toward the sea over the surface. As soon as any surface becomes subject to subaerial processes, the waters from rain and melting snow begin to modify it. That part of the precipitation which does not sink in nor evaporate, gathers into the lower places of the surface and runs off in streams rather than in sheets. As these streams run over the surface of the land they pick up the finer particles of the surface. Once picked up, these particles are carried along with the stream. The water not only cuts into the surface by picking up material from the bottom and sides of its channel, but also by using these small pieces as tools with which to acquire more material. Every sand grain transported rubs over the surface and cuts a little as it goes. A very great many grains of sand rubbing for a very great length of time, are sometimes sufficient to cut great gashes and gorges even in solid rock. The process starts by the development of a gully, the gully grows into a ravine, and the ravine into a river valley. The water in the bed of the stream deepens the gully, that which flows in from the sides broadens it, and that which comes in at its head lengthens it. The result is a valley.

STAGES OF VALLEY DEVELOPMENT.

While it is young, a valley is steep sided, since its bottom is being cut down so fast that the water does not work long enough at one level to wear back the sides and give them gentle slopes. The stream flows swiftly down a steep gradient. Falls and rapids are common. A cross section of a *young* valley is V-shaped (fig. 16, *a*).

As the development of the valley continues, its shape changes. A stream cannot cut its valley bottom lower than the body of water into which it flows. When the valley gets as deep as it can be cut by its stream under the existing conditions, it is said to be *at grade,* or to have reached *base level.* When a stream reaches grade, downward cutting practically ceases, and cutting on the sides becomes relatively more important. It is readily seen that after the stream ceases to cut downward, the lateral cutting which continues as before will work for a longer time at one level and will tend to undermine the sides of the channel at that level. The overhanging parts will then fall, making a flat. In this stage the stream will cut the sides fastest in places where the material is the least resistant, and will come to have a more curving course than it had in extreme youth. It will come to swing from side to side, cutting more on the outside of the bends than elsewhere, for there the current strikes the wall of its channel with most force. Filling takes place mostly on the inside of the curves. This process continues until a flat is developed along the stream, and this flat becomes broader as the process goes on. In this condition a stream is said to be *meandering,* and the flat which is developed is known as a *flood plain.* At the same time the atmosphere is attacking the upper portions of the walls of the channel and causing them to wear back from the stream, thus forming a valley with sides sloping toward the channel. When a valley has reached such a stage that it is widened much faster than it is deepened, such that a flood plain of low gradient is being developed, it is said to be *mature.*

In cross section, a mature valley is U-shaped or flat bottomed rather than V-shaped. Its gradient is relatively low, and falls and rapids are less common. The side slopes are less steep, on the average, than in youth (fig. 16, *b*).

If these processes go on for a sufficiently long time without interruption, the depression made by running water becomes a broad valley with very gentle slopes on either side, and a very broad, flat bottom. The stream will be too sluggish to carry any but the finer particles of sediment, except in time of flood. In such a stage a valley is in its *old age.* Figure 16 is a section across valleys typical of the three stages recognized in their development.

Effect of Stream Erosion on a Land Surface.

It is readily seen that if a stream has the power to cut its valley down to base level, many streams will be able to reduce a great area to a low level. This is the goal of the work of streams on a land surface.

In cutting into a plain, streams must increase its roughness and relief. Most of the land does not change its altitude at first, while certain parts of it are lowered by the streams. As the streams work headward and send out tributaries, more and more of the surface becomes affected by them, and it becomes more and more irregular. But obviously there is a limit to the amount of relief a region can have. When the main streams have cut their valleys down to grade the maximum relief has been reached. The elevations become no higher and the valley bottoms no lower. After most of the streams have ceased to cut downward and lateral cutting and weathering of valley slopes have become important,

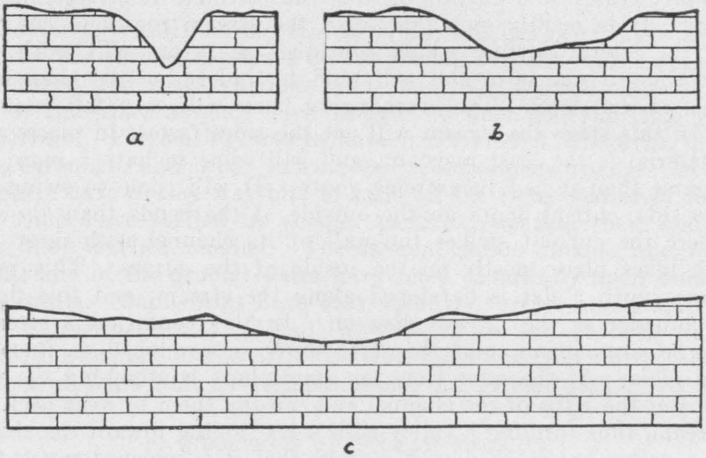


Figure 16. Diagrammatic sections across a river valley in three stages of its development.

(a) Sections across a young valley (from Dunlap, Ill., topographic sheet).
(b) Section across a mature valley (from Dunlap, Ill., sheet).
(c) Section acrcss an old valley (from Joplin, Mo., topographic sheet).

it is clear that the surface will again become more regular. The streams will widen their flood plains while the divides become lower and lower. The final result will be a plain, perhaps somewhat similar in topography to that with which the region started, but at a lower level.

All these stages in the reduction of a land surface to a base level make up a *cycle of erosion*. When the work of degradation is in its early stages, the region is said to be *young;* when the work is well advanced, say half done, it is *mature;* and when it is nearly all done, it is *old*. In a young plain the greater part of the flat land is on the uplands above the stream valleys. Streams have done little in cutting out their valleys, and there are large areas yet untouched by the streams working headward. The uplands are likely to be poorly drained, especially if there were depressions without outlets in the surface to begin with. The valleys themselves are relatively few in number, and show the characteristics of youth rather than of maturity or old age. Flats of any considerable width are not yet developed in the valley bottoms. Many of the streams are intermittent, not yet having cut their valleys below the level of permanent ground water.

A region becomes mature when it reaches its maximum of irregularity. In this stage of the cycle the original plain has been thoroughly dissected, so that there is little flat land at the original level. The streams have not yet developed very extensive flats in their valley bottoms. A large part of the surface has been reduced to slopes.

In old age, most of the work of reducing a region to a low level has been done. The streams have developed broad flood plains which make up a considerable part of the total surface. The slopes to the valleys are gentle. There is little or none of the original surface left intact. The divides have been brought low, until they stand, as a rule, but little above the flood plains. The streams are at grade and carry only fine sediment. The slopes are gentle and the relief slight. The surface is again a plain.

Effect of Erosional Processes on the Surface of the Drift.

Running water has been doing the sort of work described above in the Wheaton quadrangle since it was left uncovered by the ice. With the first rain, or with the melting of the first snow after the ice disappeared, gullies began to be developed by the water which ran off from the hills into the depressions, and a cycle of erosion was started.

AGE OF THE VALLEYS.

It must be remembered that of the valleys of this region, those occupied by the East and West Branches of Dupage river were not developed by stream erosion alone. They already existed as valleys when the ice left the region.

Of the rain which first fell on the surface of the drift, only that which fell in or near the two large valleys ran off the surface freely. Over most of the area is the rolling surface of the ground and terminal moraines, with many undrained depressions. Much of the water which fell sank into the loose drift, or ran off from the elevations and into the depressions. This gave little opportunity for the development of valleys to any great extent. The gradients from the tops of the elevations to the bottoms of the depressions were low, and consequently valley-making was a slow process until after the depressions were drained. But the water which fell on the sides of the original large valleys ran down their slopes to flow off in the branches of the Dupage river. With the steep slopes to these valleys, the running water descending to them was able to develop valleys much faster than elsewhere in the quadrangle. Hence, though we see few recent valleys of erosion in the general upland, they are found in great numbers along the sides of the two tributaries of Dupage river. Some of these valleys have extended themselves back for a mile or two into the upland plain, but for the most part they are restricted to the immediate vicinity of the two large valleys.

These little tributary valleys show all the characteristics of youth. They are distinctly V-shaped, their sides being steep and their bottoms narrow. None of them have flats. Plate XII, *B*, is a photograph of a small typical valley in the drift of this region and figure 17 is a section across it. No flood plains, or other evidences of a later stage of development than youth are seen. The stream gradients are steep. According to the topographic map, gradients of 50 feet in 150 feet are common. That is, a stream falls 1 foot in every 3 feet of flow, measured horizontally. This fall takes place over miniature rapids or falls, occasioned by small differences in the resistance of the drift. Where there is a bowlder in the bed, there is a small water-fall occasioned by running water wearing away the softer clay below the bowlder faster than it does

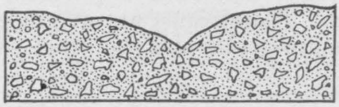


Figure 17. Section across a typical valley in sections 13 and 14, Lisle township. Vertical scale exaggerated 15 times.

the bowlder itself. Where the material is uniform in character, there is a uniform slope. A further evidence of youth is found in the fact that all the streams in these valleys are intermittent. The ravines rise so abruptly from the bottoms of the larger valleys that they immediately get above the level of ground water. The run-off from rains and snows has not had time since the glacial period to cut them below this level, and consequently in most cases they contain running water only after rains.

In some of the valleys near Naperville a slightly later stage of development is shown. For instance, the stream in the Lutheran Camp Grounds has begun to meander to some extent, and a narrow flat has begun to be developed along the bottom of the valley. This has hardly gone far enough however to call the valley mature, as the flats are narrow and the valley walls are still very steep.

EROSIONAL DEVELOPMENT OF THE REGION.

Considered as a whole, very little work has been done by the streams in this region since the ice melted.

One of the first results of stream erosion on a surface such as is found in this quadrangle is to drain the depressions left without outlets by the ice. This has been done in a very few places only. Ponds and marshes without outlets are common all over the region, but in some places, especially near the two main drainage lines, the heads of valleys have reached back so as to tap a marsh or a pond. Some marshes have been entirely drained, and some but partially drained, as in the case of the swamp on the corner common of sections 14, 15, 22, and 23, Milton township. A small stream flows from the lowest swamp to the southeast in a post-glacial cut 3 feet deep. Before the stream made this cut the water stood 3 feet higher in the swamp than it does now. This must have connected all the parts of the swamp and extended its area slightly. In some few inconspicuous cases also, two undrained depressions seem to have been joined by the cutting of overflow water which runs from one to the other. Such a case occurs in the south central part of sec. 33, Bloomingdale township.

As previously shown the valleys are young and restricted to narrow strips around the border of the uplands. In these strips the land is dissected, and the topography is due to erosion. The elevations are the divides between the streams, and they run parallel with the valleys. Every depression leads to a lower one. Starting at the head of any one of the small valleys, one could follow it down to the Dupage river, down the Dupage to the Des Plaines, becoming constantly nearer sea level, down the Des Plaines to the Illinois, thence to the Mississippi and the Gulf. But the strips of well-dissected land form a very small part of the region. As a whole the upland has still the shape which was given it by the ice. Elevations and depressions are arranged in no order. If a depression is elongate in any direction, the adjacent elevations are not usually so elongated. If an elevation trends north and south, the depressions associated with it may trend east and west, or may not be elongated at all, but round. One depression does not lead to any other depression. To one starting in one of the lower parts of the surface, there would be constant ups and downs, without any constant slopes either of ascent or descent. In short, elevations and depressions have no orderly relation to one another and have no relation to streams or stream valleys.

Very little has been done by the streams in their work of reducing the region to base level. The region is in early youth in the present cycle of erosion.

UPBUILDING OF THE LAND SINCE GLACIAL TIMES.

In direct opposition to the process of weathering and erosion in degrading the land, there are some processes which tend to build up or aggrade the land. As is so well illustrated in this region, ice sometimes builds up the surface by the deposition of its drift. In some places, streams deposit material which they have eroded from other places, thus *aggrading* the land in the former places. Winds sometimes deposit great masses of sand as dunes.

The amount of material which has been eroded from the surface of this region is slight, and most of that slight amount has been taken entirely out of the region. That which was taken by the small streams from the sides of the valleys of the East and West Branches of Dupage river, went into the larger streams, and has been carried out of the region by the rivers. Even the large streams have not deposited enough material along their sides to be of any geographic importance, and the smaller streams are not depositing at all. There are some small strips of alluvium along the two branches of the Dupage river, but they are so narrow as to be almost negligible.

On the upland plain away from the main valleys, where an erosional topography has not been developed, all the material which has been eroded from the elevations has been deposited in the depressions, without producing much effect. Many ponds and marshes in the area are slowly being filled with sediment washed down the surrounding slopes, and some have doubtless been filled already. Part of the black muck of the swamps has been washed down from the sides, and part is organic matter left by the death of vegetation which grew there.

The waters which sink below the surface also sometimes play a part in strengthening the land mass rather than in tearing it down, although its work is usually degradational. As the water seeps through the pores and cracks of the rock it dissolves the soluble parts and thus helps to weaken the land. But the substances which are extracted from the drift in some places, may be added to it in others. This tends to cement the drift where the addition occurs.

One example of cementation is the coating of the pebbles of the till already referred to in another place. The coating material is calcium carbonate which was dissolved from one part of the drift and deposited in another where conditions of temperature and pressure were favorable for precipitation rather than for further solution.

A still more striking illustration of this same principle is found in the "petrified gravels" spoken of by the well drillers. In drilling wells, these men often strike a part of the drift where the pebbles of the gravel have been cemented together to form a hard rock. These "petrified gravels" of the well drillers are what geologists know as *conglomerates.* Though such rocks were reported from several wells, only one outcrop of it was seen in the region. This was in a small gravel pit in the north central part of sec. 26, Bloomingdale township. It consists of small pebbles up to 4 inches in diameter, cemented together firmly with calcium carbonate. The pebbles do not differ in any respect from the pebbles in other gravels of the region, nor from those in the unconsolidated gravels over and under the cemented layer in this pit. This simply means that the water which percolated through this bed of gravel now represented by the conglomerate was charged with calcium carbonate, and that conditions of temperature and pressure were such, and bore such relation to the content of the water, that the water precipitated some of its dissolved materials, rather than dissolved more from the limestone of the gravel. The precipitation took place in the spaces between the pebbles and was in sufficient quantity to bind them together firmly.

These and similar processes do not nearly balance the processes of weathering and erosion, which are constantly weakening and tearing down the land. In general, the results of all slow processes working on the land mass are degradational rather than aggradational.

CHAPTER V—CONCLUSION.

From all the foregoing observations it is seen that various processes, and the same processes at various times, have been in operation to bring about the present land conditions in this region. Seas once covered the region. Sands and muds were worn from adjacent land masses by the processes of weathering and erosion, were transported to the sea by streams, and deposited along its shores. Animals made shells of calcium carbonate, and dying, left them on the sea bottom. These sands, muds, and shells became cemented by the deposition of other material, and sandstones, shales, and limestones resulted. The seas withdrew, and the surface once covered by them was subjected to processes of weathering. Rocks were broken up and prepared for transportation by running water. Streams used the fragments as tools with which to wear out valleys for themselves in the surface. These processes were in operation for long periods of time, and the surface was probably worn down, uplifted and worn down again, in several cycles of erosion. Five great ice sheets advanced over the region in succession from the north. The last of these ice sheets left extensive deposits in the region, in the form of a thick mantle of mixed materials which it had picked up from the surface to the north, especially in the Lake Michigan basin. The edge of the ice sheet was stationary or nearly so for a time over part of the region, and the terminal moraine and the outwash material resulted. Since the ice finally withdrew from the region, the various processes of weathering and erosion again became active, but their results have not been great.

APPENDIX.

RECORDS OF WELLS IN THE WHEATON QUADRANGLE.

SHALLOW WELLS.

No.	Depth.	Materials, etc.	Thickness.
	Feet.		*Feet.*
1	7	Clay	3
		Gravel and sand	4
2 (*a*)	158	Drift	100
		Limestone	58
(*b*)	8	Yellow clay	4
		Gravel	4
(*c*)	97	To rock	97
3	62	Gravel	62
4		See table of deep wells	
5	71	Gravel and blue clay	70
		Rock	1
6	112	To rock	100
		Rock	12
7	100	Gravel and clay	64
		Rock	36
8	26	Bottom in sand	
9	86	Bottom in rock	
10	140	Soil, loam and clay	7
		Quicksand with yellow clay	5
		Clay	113
		Rock	15
11	90	Clay and hardpan	30
		Rock	60
12		See table of deep wells	
13	130	Enters rock at unknown depth	
14	87	A few feet in rock	
15	72	No rock, water in gravel	
16	91	Gravel	60
		Clay	11
		Sand	20
		No rock	
17	170	In rock	26
18	120	Drift	100
		Limestone	20
19	122	Clay	100
		Limestone	22
20	140	Drift	125
		Limestone	15
21	150	Sand, gravel, clay	140
		Limestone	10
22	95	All drift	
23	130	Mostly sand, no rock	
24	168	Red clay	30
		Blue clay	120
		Conglomerate	10
		Limestone	8
25	174	Clay and bowlders	150
		Conglomerate	6
		Rock	1½
26	148	Clay	130
		Sand	12
		Limestone	6

Shallow Wells—Continued.

No.	Depth.	Materials, etc.	Thickness.
	Feet.		*Feet.*
27	231	Drift	140
		Limestone	91
28	274	Drift	124
		Limestone	150
29 (*a*)	58	Drift	30
		Limestone	28
(*b*)	127	Clay and a little sand, "petrified gravel". Rock	....
30	176	Red clay	10
		Blue clay	160
		Conglomerate	3
		Limestone	3
31	96	Gravel and sand. Water in coarse gravel	....
32	130	To rock	130
33	183	Drift	158
		Limestone	25
34	167	Clay	80
		Sand	20
		Coal (?)	1
		Sand	56
		Limestone	10
35	144	Drift	140
		Limestone	4
36	163	Drift	158
		Limestone	5
37	186	Drift	171
		Rock	15
38	117	Drift	100
		Limestone	17
39	190	Gravel and sand	174
		Limestone	16
40	194	Gravel and sand	178
		Limestone	16
41	137	Drift with one layer of gravel	133
		Limestone	4
42	65	Sand	12
		Clay and gravel	53
43	100	Drift	100
44	140	Drift	124
		Limestone	16
45	129	Yellow and blue clay with pebbles	112
		Limestone	17
46	131	Clay	117
		Rock	14
47 (*a*)	307	Clay and gravel	100
		Rock	207
(*b*)	146	Stony clay	136
		"Petrified gravel"	6
		Limestone	4
48	170	Yellow clay	30
		Blue clay	110
		Blue limestone	30
49	90	Blue clay	80
		Limestone	10
50 (*a*)		Wheaton town well. See table of deep wells	
(*b*)	106	Clay and sand. A little loose gravel 45-50 ft. from surface	105
		Limestone	1
(*c*)	144	Clay	130
		Limestone	14
51	185	Drift	148
		Limestone	37
52	176	Stony clay	172
		Limestone	4
53	172	Drift with some sand	154
		Limestone	18
54	150	Drift	100
		Limestone	50
55	78	Clay with sand and gravel in bottom. No rock	78
56	130	Drift	108
		Limestone	22
57	97	Drift. Water in sand	97
58	143	Till	94
		Limestone	49
59	72	Gravel	72
60	196	Clay with streaks of gravel	116
		Limestone	80
61	145	Clay and gravel	120

Shallow Wells—Concluded.

No.	Depth.	Materials, etc.	Thickness.
	Feet.		*Feet.*
		Limestone	25
62	44	Sand	44
63		See table of deep wells	
64	30	Drift	30
65	100	Drift	90
		Limestone	10
66	60	Drift	60
67	7½	Black soil	2
		Yellow clay	2½
		Blue clay	5
68	49	Gravel with one layer of yellow clay, 6-7 ft. thick	49
69	125	Drift	115
		Limestone	10
70 (*a*)	113	Clay	50
		Fine sand	55
		Limestone	8
(*b*)	125	Clay	60
		Sand	60
		"Petrified gravel" rock	5
71	121	Drift	112
		Rock	9
72	72	Drift with a little sand 24 ft. from surface	70
		Limestone	2
73 (*a*)	87	Clay	77
		Limestone	10
(*b*)	52	Blue clay. Water in gravel 52 ft. from surface	52

DEEP WELLS.

No.	Location.	Depth.	Materials, etc.	Thickness.
		Feet.		*Feet.*
4	West Chicago	869	To rock	90
			Limestone	269
			Shale and limestone	346
			Sandstone	134
12	Naperville	1,425	Loam and loose rock	20
			Limestone	95
			Limestone streaked with shale	190
			Limestone	341
			Sandstone	129
			Limestone streaked with shale	61
			Limestone	100
			Shale	3
			?	6
			Sandstone	5
			Limestone	315
			Sandstone	155
			Dirty sandstone	5
*50 (*a*)	Wheaton	180	Surface soil	6–8
			Gravel	12
			Sand and clay, clay decreases in amount downward	16
			Yellow clay (hardpan)	4–5
			Blue clay, few inches quicksand and gravel on top of limestone	60
			Limestone	80
63	Downers Grove	2,021	Surface material	100
			Limestone	170
			Shale interbedded with limestone	210
			Limestone	337
			Sandstone with slight amounts of limestone, shale, and sandy marl	321
			Limestone with some sandstone and shale	762
			Sandstone	121

* Though this is not one of the deep wells of the region, it is placed in this table because if affords an ccurate and detailed section.

LIST OF PUBLICATIONS.

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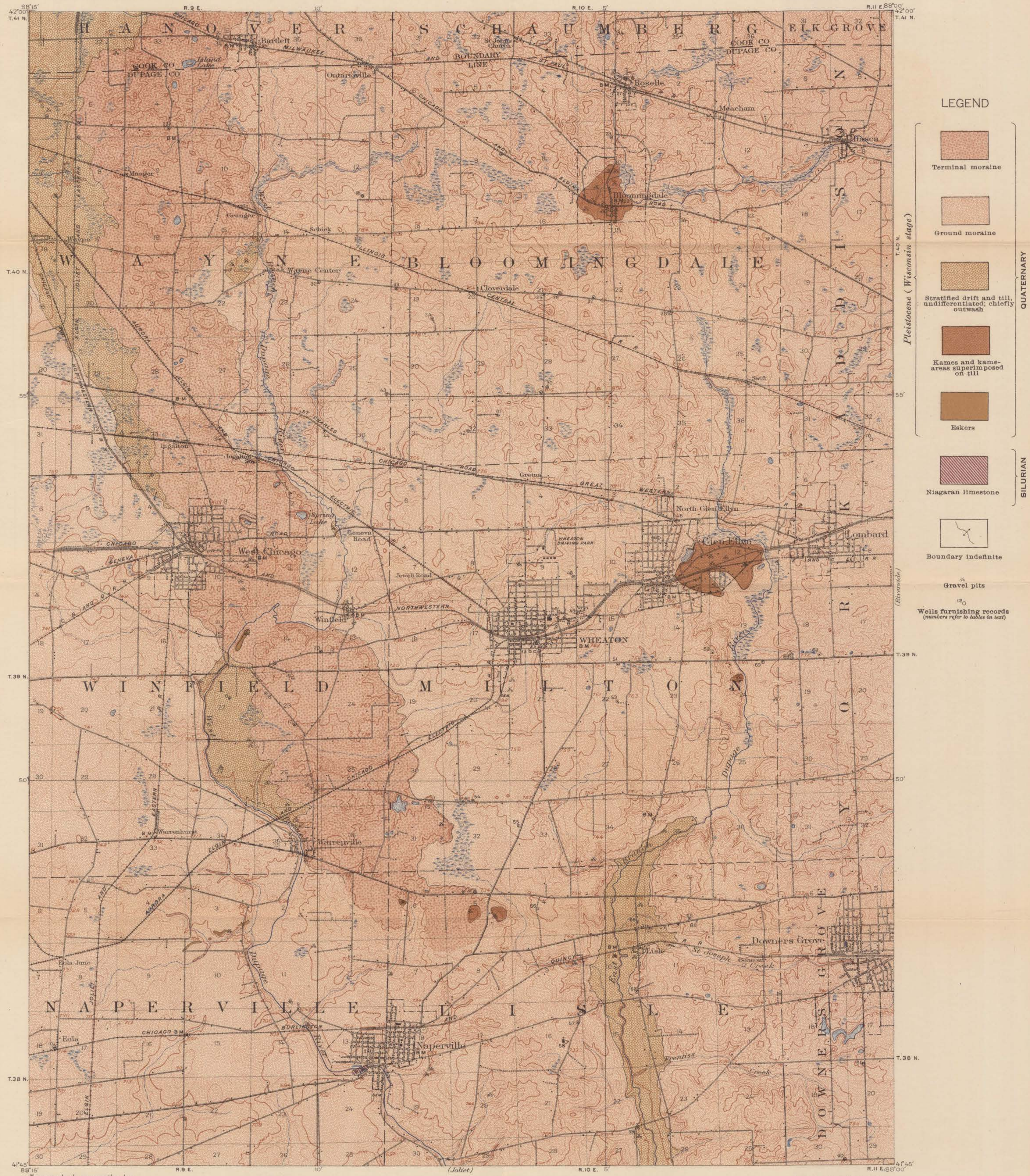
GEOLOGY OF THE WHEATON QUADRANGLE

BULLETIN NO. 19. PL. II



Topography in cooperation by
U. S. Geological Survey
George Otis Smith, Director
Illinois State Geological Survey
H. Foster Bain, Director

Scale $\frac{1}{62500}$

Contour interval 10 feet.
Datum is mean sea level.

Consulting Geologist Prof. R. D. Salisbury
Geology by Arthur C. Trowbridge